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The Seventy-Second Meeting of the American Astronomical Society

By DEAN B. McLAUGHLIN

Several months ago, the American Astronomical Society received a cordial, and most welcome, invitation to hold a meeting at the Hall of the American Philosophical Society in Philadelphia. It was accepted with alacrity, and then, with an eye on the possible attendance, the Executive Committee chose Wednesday and Thursday, June 28 and 29, during the one week when colleges on the three-term basis had a breathing spell. Mr. Wagner Schlesinger, Director of the Fels Planetarium, and Miss Julia Noonan, Assistant Secretary of the American Philosophical Society, were "drafted" to serve as local committee. The main outlines of the program were drawn up in February when the Secretary of the Astronomical Society stopped off in Philadelphia for a few hours.

Philadelphia's location near the center of gravity of Atlantic Coast astronomy was expected to assure a good attendance. As it turned out, the most optimistic predictions were considerably exceeded by the fact.

The President and Secretary boarded the New York, New Haven, and Hartford's "Quaker" separately Tuesday night, and neither saw the other until the train reached Philadelphia the next morning. There they met at the extreme outer tip of the platform (the train extended even farther) and walked what seemed like half a mile to Broad Street Station. Getting a taxi was not perfectly simple, but a stray one was finally hailed.

When they reached the Hotel Benjamin Franklin, which was to be hotel headquarters, the first sight that met their eyes was a large banner with the strange device: "Welcome Cleveland Indians." They registered, and learned that their rooms had not yet been vacated by the tenants of the previous night (some of the Indians, no doubt). This is something one gets accustomed to in these days of hectic travel and lodging conditions; it was, after all, pretty early in the morning. Some other members who had come the previous night had arrived late and rooms had not been held for all of them. However, accommodations were found for all,—at other hotels in some cases. As one of them remarked, he came out ahead on the deal; his room cost less than he had expected to pay.

Other members of the Council were in the lobby when the President and Secretary arrived, and all were hungry. So, as soon as registration was completed, they all repaired to the Coral Grill downstairs, for

breakfast and a Council meeting, which began very nearly at the scheduled time, 8:30. Breakfast meetings of the Council are all right except for the risk of the minutes becoming scrambled with the eggs. The meeting lasted until within a few minutes of the scheduled first session for papers. The Council members walked to the Hall of the Philosophical Society at Independence Square, about four blocks away. On the way they discovered that it was a hot day and was going to be hotter.

The meeting was called to order about 10:30, with the meeting room pretty well filled. President Shapley first called upon Dr. W. F. G. Swann, the Secretary of the American Philosophical Society. Dr. Swann gave a brief address of welcome, in which he remarked that he was present in two capacities: first, as a physicist to spy on us, and second, as Secretary of the host Society, to see that we did not damage their property. Dr. Shapley responded and assured him in the first place that we had nothing to conceal, and in the second that we would not wreck the furniture.

These formalities over, the program of papers was started upon, and several papers were presented before it was time to adjourn for the photograph. The group picture is even more astronomical than it looks, for it was taken almost on the site of an early astronomical observatory of David Rittenhouse.

Luncheon was "catch as catch can"; members went wherever their fancy dictated,—or wherever they could get in. There are plenty of eating places within a few blocks of Independence Square. The next session was not to begin until 3:30. Between luncheon and the afternoon session the time had been set aside for visits to local spots of interest, including Benjamin Franklin's grave, the Betsy Ross House, and of course Independence Hall, right next to the meeting place. Some members made the tour; others took advantage of the respite from meetings to relax and cool off,—or try to.

There was a good attendance again at 3:30. First on the program was the annual business meeting. Most members had already voted by mail, and those who had not done so were given ballots. The tellers, Mohler and Mrs. Hogg, then retired to count the votes. The result, which was announced some time later, was as follows:

For Vice-President	J. A. Pearce
Secretary	D. B. McLaughlin
Treasurer	Keivin Burns
Councilors	John S. Hall
	N. U. Mayall
	Peter van de Kamp
Member, Division of Physical Sciences, National Research Council	John C. Duncan

Six nominations were made from the floor for members of the nominating committee, whose duty it will be to prepare a slate of candidates for the 1945 election. Three were elected. Lieut. James Cuffey, having received the highest number of votes, was declared chairman. Other members are J. J. Nassau and N. U. Mayall.

When asked for a show of hands on the question of whether to hold or not to hold a winter meeting (probably at the end of February) a large majority of those present were in favor of such a meeting. The place has not been selected, but the President and Secretary will handle arrangements, unless it should develop that travel conditions become so bad as to make a meeting inadvisable.

The Society standing, the Secretary read the list of those taken by death during the past year:

Felix Aguilar
David E. Hadden
Jesse Pawling
Frank Schlesinger
Elliott Smith
Curtis H. Veeder
Samuel Wifvat

The business meeting concluded, a few technical papers were presented, and the meeting was then turned over to the Teachers' Conference. Discussion centered on two main topics: the teaching of navigation and what sort of astronomy to teach in the post-war liberal arts college. Those actively engaged in teaching are evidently far from being perfectly agreed on just what should be emphasized and how it should be taught, but this is a healthy sign, and they have enough ideas and initiative to give us confidence that it will be done well and that it will be worth while.

The conference adjourned, leaving just a comfortable time interval for returing to the hotel and preparing for the Society dinner. At 6:45 a large crowd gathered on the mezzanine floor near the entrance to the Washington room. Places had been set for one hundred, just in case there were more than the expected eighty-odd, but even that was not enough, and two more tables had to be set up on short notice. The delay was hardly noticeable; everybody was accommodated and dined on fried chicken.

In lieu of after-dinner speeches, a few members presented papers which could be given without the use of slides, thus helping to avoid congestion of the program next morning. The results of the election of officers were announced at this time. When it was learned that the Secretary and Treasurer (who had run unopposed) had been reelected, there were chuckles from a number of those present. It isn't quite so funny to the officers in question; they have to do the work! This portion of the program was concluded with the presentation, by Mrs. Gaposchkin, of a resolution of thanks to our hosts, who had made the meeting "smooth-running, enjoyable, and everything but cool."

The dinner and speeches over, the session adjourned to the Fels

Planetarium, following the directions of the local committee. Some stopped on the way for cooling refreshments, but all caught the right street-cars and arrived in time for the demonstration. The air-conditioned planetarium dome was a welcome relief from the outside heat.

The show consisted of one of the regular performances, almost as it is given for the general public. The audience was taken on a simulated journey by rocket ship to the moon and set down inside the crater Franklin, whence they witnessed sunrise and sunset lights and shadows on the jagged crater walls, and the rotation and phases of the earth, which hung there very convincingly in the sky. They saw the monthly apparent rotation of the celestial sphere, and an eclipse of the sun by the earth, complete with corona and the red ring of sunlit terrestrial atmosphere, which shed a strange coppery light on the crater walls. It was all perfectly good authentic astronomy, but presented in a novel and ingenious way. We should add that the rocket ship returned safely to earth and landed without the slightest jar.

Immediately after the demonstration, the visitors were guests of the Rittenhouse Astronomical Society. Refreshments were served in the locomotive room. There, beside old engines of DeWitt Clinton and similar vintages, is a huge modern locomotive on a track long enough to permit it to move about one revolution of the drivers. The controls in the cab actuate electric motors which move the locomotive forward or backward. Some of the astronomers, and especially some of the ladies in the party, had a marvelous time putting it through its paces. Perhaps the contents of the punch bowl had something to do with these activities. It is reported that some of the guests stayed until about 12:30.

Thursday morning the members of the Council had to get up for an eight o'clock meeting at breakfast, while the general membership could sleep more than an hour longer. All Council business was finished up, and the session for papers was opened on time at 9:30. Between then and noon, all the remaining program of papers was completed. One member who presented a paper by an absent author concluded it by remarking: "This completes the presentation of the paper. I will now step down and argue with myself," and proceeded to discuss the paper.

Near the close of the session, directions were given for transportation to the several observatories in the vicinity: Flower, Cook, Sproul, and Haverford. Their locations are such that, in these days of A books, it is practically impossible to visit more than one of them in an afternoon. Some members visited one or another of the observatories, but probably a majority did not.

The Thursday morning session concluded the meeting and, although many astronomers were to be seen at luncheon in the Coral Grill at the Benjamin Franklin, the visitors rapidly dispersed. The Secretary

and two other diners with whom he was "in conference" outsat all others, but departed before the first supper guests came in.

Up to within a few days of the meeting, the Secretary had been haunted by two possibilities in connection with the return trip. In the first place, the return train, the "New Englander" was reported sold out. In the second place, if he did get a berth through a last-minute cancellation, there was another hazard. Passengers may board the New Englander at Broad Street at 10:00 P.M. But at 12:20 they are likely to be rudely awaken by a terrific jolt on starting, and then they are hauled out into the yards, where their cars are turned over to neophyte engineers to use for practice in coupling Pullmans together. Finally, thoroughly exhausted, they are sent on their way to Boston.

However, luck was with him this time. A visit to Washington was "on the books," and it could be conveniently placed on Friday. This meant a chance to relax after the meeting, which was exactly what he did. And when one has a hotel room in Philadelphia and an appointment in Washington the next day, one stays in Philadelphia that night!

The attendance at the meeting was much larger than expected. Names of 88 members were recorded, and the number of guests is not accurately known, but 102 faces, or portions thereof, appear in the group photograph, and probably some non-members did not appear in the picture or record their names. The number of papers on the program was 24, exclusive of the discussions at the Teachers' Conference.

The following new members were elected to the Society, by action of the Council:

William P. Bidelman
Carlos U. Cesco
Roy W. Delaplaine
Guilliermo Haro
Miss Isabel Harris
Miss Ruth E. Hayner
Herbert Jehle
Mrs. Margaret Kiess Krogdahl
Walter J. Miller, S. J.
Miss Martha Morrow
Miss Margaret Olmstead
E. Gunther Ruening
Jorge Sahade
Harvey A. Zinszer

This also sets a record for a wartime meeting; only five new members were elected at Cincinnati! At least there seems to be considerable hope of astronomy continuing to be very much alive, though astronomers are temporarily engaged in other activities.

HARVARD COLLEGE OBSERVATORY, CAMBRIDGE, MASSACHUSETTS, JULY 17, 1944.

The Milky Way

By BART J. BOK

(Continued from page 278)

III. Problems in Stellar Motion

Local Characteristics. The researches of the past four decades have given us a fairly complete picture of the distribution of stellar motions for the regions near the sun. The solar motion of 20 km/sec toward the apex at R.A. 18^h, Decl. $+30°$ represents a good average, but it has been shown definitely that it does not hold strictly for all groups of stars. Deviating values for the position of the solar apex have been found in several cases and some of the derived speeds are quite different from the standard value. Several factors contribute to these divergences, the most important of these being apparently the effects of extended moving clusters, or streams, and the asymmetry of stellar motions.

The exact status of the extended moving clusters is at present in doubt. Some of them, such as the Taurus and Ursa Major clusters, are certainly real, but recent work, especially by Smart, has thrown considerable doubt on the reality of the extended B-star clusters in Scorpio-Centaurus, Perseus, and Orion, which were generally accepted as real. According to Smart the members of these groups may be regular field stars with low individual motions.

The question of the reality of extended moving clusters is an important one that will require careful attention in the post-war years. The presence of groups of stars with members that are so far apart as to have no gravitational effect upon each other would pose a startling dynamical problem for a rapidly rotating galaxy.

Closely allied to the problem of extended clusters or streams are the puzzles relating to the K-effect. This represents an effect in the radial velocities, which is especally marked among the brighter B stars. When averaged all over the sky, their radial velocities do not cancel as they would be expected to do if solar motion and regular star streaming were the only contributing factors. Instead an average velocity of regression is found, amounting to several kilometers per second. It may be explained in part as a shift suffered by light quanta emerging from a massive star, *i.e.*, as a relativity effect. The observed effect is, however, too large to be wholly explained in this fashion. Plaskett and Pearce claimed to have found the cause in the contribution from the extended Scorpio-Centaurus stream, but a subsequent analysis by Smart threw doubt on the validity of their conclusions. The K-effect will require careful further investigation, observational as well as analytical.

The phenomenon of the asymmetry in stellar motions, apparently one

of the greatest puzzles of twenty years ago, has found a very satisfactory explanation in the theory of galactic rotation. Observationally

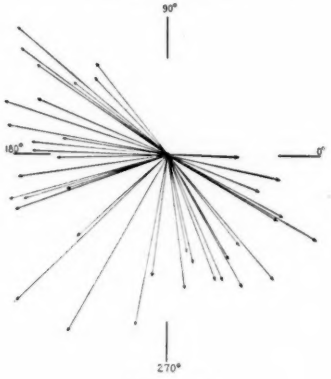

FIGURE 5

THE ASYMMETRY IN STELLAR MOTIONS

A diagram by Oort, showing the distribution of the directions of the motions (parallel to the galactic plane) of the stars with velocities in excess of 60 kilometers per second.

it is revealed as follows: When a plot is made to show the distribution of directions of the motions of the stars of low velocity (less than 60 km/sec), there is no suggestion that certain directions are favored to the exclusion of others. The effects of normal solar motion and streaming are indicated, but no other effects are found. All this changes completely when plots are made to show the distribution of directions for stars with speeds over 60 km/sec. It is found that hardly a single star moves in the direction of galactic longitudes 20° to 90°, with the center of the quadrant of avoidance at galactic longitude 55° (in Cygnus).

To explain the phenomenon, we begin by noting that the direction of galactic longitude 55° differs by exactly 90° from that toward the galactic center. In other words, it marks the directon in which the sun, with the majority of its neighbors, whirls around the galactic center in a nearly circular orbit at a speed of perhaps 250 km/sec. All motions measured from the earth are referred to the sun. A star with a measured velocity of only a few kilometers per second will in reality move around the galactic center at very nearly the same rate as our sun. Let us suppose now that we have a star with a measured speed, taken with respect to the sun, of 100 km/sec in a direction opposite to the sun's motion around the center. Such a star would in reality be a slow-mover, going around the center at the leisurely pace of 250 — 100

= 150 km/sec, lagging not only behind the sun, but also behind the majority of stars in our vincinity. A star with a velocity of 100 km/sec (with respect to the sun) and moving *in* the direction of galactic rotation would, however, have a speed of 250 + 100 = 350 km/sec with respect to the center of our galaxy. Such stars would in all probability escape promptly into intergalactic space and their apparent absence in our velocity surveys can thus be readily understood. The stars that are observed to have velocities of 60 km/sec and more in the direction opposite to the rotation move in elongated orbits rather than circular ones around the galactic center; they are in reality slow-moving objects.

The search for, and study of, high-velocity stars remains a fascinating subject for further investigation. One of the best known groups of high-velocity stars are the cluster-type variables. Certain types of dwarfs and red giants also seem to prefer this status, but no high-velocity stars are found among the regular Cepheid variables or the B stars. In post-war studies of stellar radial velocities and proper motions, it will be of interest to keep watching for possible hight-velocity interlopers. There is always the chance that one may discover a real high-velocity star moving in the direction of galactic rotation and presumably on its way out of our galaxy.

The evidence relating to geneneral star streaming, while incomplete in many ways, seems to fit well into the general picture. It has been shown not to be a local phenomenon, but to extend to at least 5000 light years from the sun, the greatest distance to which it has been possible to penetrate with the aid of proper motions (Radcliffe catalogue).

It is shown in the theory of galactic rotation that local star streaming can be expected for stars whose motions differ slightly from purely circular motion around the center of the galaxy. The simple theory predicts that the average spread of the motions around the mean should be appreciably larger for the velocity components toward and away from the galactic center than for the components at right angles to this direction. The axis of maximum velocity dispersion should, therefore, point directly toward the center of our galaxy. In reality this does not prove to be exactly the case. The galactic center in Sagittarius is near galactic longitudes 325° to 330°, but the observed direction for the axis of maximum dispersion of velocity points towards galactic longitude 340° to 350°.

The explanation is probably to be sought in some effect caused by local structure. There is little doubt that the simple picture of a smooth, rotating galaxy with differential motions is only a first and very rough approximation to the truth. It is to be expected that local structure (spiral arms, clustering) will have its effect on the distribution of the deviations from pure circular motion. Further observations relating to star streaming are urgently desired. Important advances in our knowledge of the local characteristics of the distribution of stellar motions are bound to come, when more abundant data on star streaming

can be analyzed in conjunction with certain details of local structure. The relation between the distribution of star densities and star streaming is an intimate one.

Important information about the make-up of our galaxy is obtained from a joint discussion of stellar motions at right angles to the galactic plane and of the density distribution in the galactic polar caps. The study of the velocities at right angles to the galactic plane may be expected to yield important results in the near future. This problem will be considered in some detail in the section that follows.

A knowledge of the distribution of proper motions and radial velocities for the regions around the sun is basic for statistical studies of mean parallaxes. The available data have made possible statistical studies to distances of 5000 light years. From these mean parallaxes important information on mean absolute magnitudes and dispersions has been obtained. Mean parallaxes promise in the future to become useful in discussions of the density distribution for the stars within 3000 light years of the sun.

Galactic Rotation. The theory of galactic rotation had its origin in the researches of Oort and Lindblad of 1926-27. In 1927 Oort demonstrated that the observations of radial velocities showed the double wave in galactic longitude, predicted by the simple theory. He was also able to give supporting evidence from the proper motions. Additional observational studies showed clearly that Oort was on the right track.

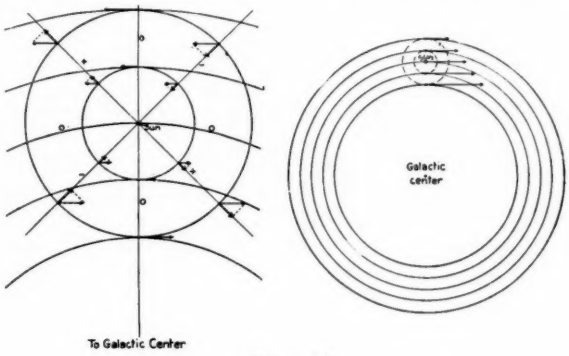

FIGURE 6

EXPLANATION OF THE EFFECTS OF GALACTIC ROTATION ON RADIAL VELOCITIES

The diagram on the right illustrates the variation in the rotational velocities with distance from the center. In the diagram on the left the region around the sun is reproduced on a larger scale. The arrows represent now the relative velocities that will be observed from the sun. The radial (line of sight) components of these velocities show the variation of the galactic rotation effect with galactic longitude.

Oort's simple formulae were supposed to hold only for relatively small distances from the sun. It was expected that at distances beyond 5000 light years additional terms would come into play, which would disturb the simple picture. This has not proved to be the case. Joy's radial velocities of Cepheid variables, for example, penetrate to distances of 10,000 light years from the sun (corrected for absorption) and these velocities show the simple harmonic wave of Oort in all its beautiful simplicity. In the post-war period the search for higher-order terms in galactic rotation will probably continue. It looks as though to obtain significant results, we will have to explore to beyond the limit of 10,000 light years reached in Joy's researches. The number of available objects beyond this limit, and bright enough to have their radial velocities measured, is probably not very great. Interstellar absorption dims the light of the distant objects that might have been used if our galaxy had been more transparent. The planetary nebulae, globular clusters, galactic clusters, O stars, novae, and Cepheid variables are about the only objects that can be observed at the required great distances. Berman has made a beginning with the study of planetary nebulae, but the subject is by no means closed. Trumpler's and Mayall's work on clusters promises to yield important results, but as the matter stands today no positive information about second and higher-order terms has as yet been obtained.

We indicated in the section on the outline of our galaxy that it still remains to be settled exactly what is the value of the speed of rotation of the sun around the galactic center. Astronomers will await with interest the publication of the analysis by Mayall of the radial velocities of fifty globular clusters. We have already indicated that Mayall's preliminary analysis suggests a value substantially less than the 250 to 300 km/sec used in the past. It seems likely that 200 km/sec may be nearer the truth.

It is extremely desirable to have an independent check on the amount of the speed of rotation and the direction of the sun's motion around the galactic center. There is always the possibility—not in the least unlikely!—that the globular cluster system partakes to some extent in the rotation of the galaxy as a whole. The higher speed of rotation is supported, though admittedly rather loosely, by the fact that it agrees well with the amount derived from a solution for "solar motion" of the radial velocities of the nearer external galaxies. For the present we should not be too eager to accept the smaller speed in preference to the higher value; 250 km/sec seems a good compromise, subject to post-war adjustment.

Galactic Dynamics. The development of the theory of galactic rotation has given renewed impetus to research in the dynamics of our galaxy. Among the most successful recent contributors to this new field have been Lindblad, Oort, and Chandrasekhar; of the earlier in-

vestigators, Eddington and Jeans have made the most important contributions.

The study of the dynamics of our rotating galaxy seems to have advanced about as far as it can profitably be carried, bearing in mind the limited nature of our information on stellar motions and stellar distribution. The theoretical framework is available for an adequate discussion of still to be discovered regularities in stellar motions. In our description of observed deviations from the simplest form of star streaming, we have already mentioned that these deviations are intimately connected with variations in the local star densities. The same holds for data on the asymmetry in stellar motions.

The most intriguing simple dynamical problem is that of the status of the extended moving clusters or streams. While there may be reasons to doubt the physical reality of some of these streams, the existence of two of them, the Taurus and Ursa Major streams, seems definitely established. The most pressing task for the observer will be to investigate whether these streams are really limited in size—as they seem to be—or whether the observed stars are only a sample from much more extended streams.

If the first alternative should prove to be correct, these extended clusters would evidently be of very recent origin. Speaking in terms of *cosmic years,* one cosmic year being the time needed by our sun to complete one galactic revolution (2×10^8 years), such rarefied clusters could hardly be expected to remain intact for more than one-quarter or one-half of a cosmic year. Since our galaxy has existed for at least fifteen (and probably more nearly one hundred) cosmic years, these extended clusters would then, cosmically speaking, be of very recent origin. The puzzle is whence they came and how they were formed. There is little indication that new extended clusters are being built up to replenish the supply after the present ones give out.

If the second alternative proves to be the right one, the student of galactic dynamics will have to account for large-scale streams in which the motions of the individual stars show a remarkable degree of regularity. The thought of correlating them with motions in spiral arms comes directly to mind. Whatever answer may be the correct one, there is little doubt that the theoretician will have a field day, once the status of the extended moving clusters, or star streams, is finally settled by observations.

Investigations in the field of galactic dynamics touch in various ways upon problems relating to the cosmic time-scale. There is at present an almost disquieting unanimity about the correctness of the short time-scale, according to which our galaxy and its component stars (as well as the universe of galaxies) would have existed for not more than 10^{10} or 2×10^{10} solar years (50 to 100 cosmic years) at the most. The observed red-shift of the distant galaxies, the clusters and binary stars in our home galaxy, and the radioactive rocks in the earth's crust, all

seem to indicate that this particular limit has cosmic significance.

Much of the post-war research in galactic dynamics will be concerned with problems connected in some way with the cosmic time-scale. Special attention will undoubtedly be given to the further theoretical treatment of problems of the stability of clusters, binary stars, and interstellar clouds of gas and dust. These investigations will be paralleled by observational studies involving peculiar motions, total masses, and dimensions of these same objects. On the theoretical side, Chandrasekhar's theorems on dynamical friction may play an important part. Observatonally, studies of internal motions in clusters, such as those carried out for the Pleiades and Praesepe by Hertzsprung, Schilt, and Titus, will be of importance. The researches on the multiplicity of interstellar lines (Beals, Adams, Wilson, Merrill) and of the sizes and total masses of dust clouds (Schalén) may become increasingly important.

In closing this section we shall mention a type of problem that is difficult to classify and that may as well be mentioned here as elsewhere. Probably the most baffling problem facing the galactic investigator today is to find a good reason why the kinematical characteristics of certain types of stars seem to be connected intimately with their physical characteristics. Why, for example, should the cluster-type variables (with periods of the order of half a day) have velocities with respect to the sun that are on the average five or more times as large as those of normal stars of similar mass and spectral type? And why should the regular Cepheids be among the stars with the smallest relative speeds? One may formulate the question differently and ask, why is it that the cluster-type variables move in elongated orbits in our galaxy and the Cepheids in more nearly circular orbits? But this is not bringing us any nearer to an answer to our question.

Evidently the remarkable observed peculiarities must have some relation to the origin of each type of star. Perhaps conditions in the nuclear regions of our galaxy were more conducive to the formation of cluster-type variables, while conditions in the outer regions would favor the birth of regular Cepheids. First attempts at a solution of the problem have been made by Stromberg and by Lindblad. One can, however, not help feeling that we have as yet not made any progress at all toward the real solution of the major problem.

IV. The Absorption Problem

Since matter in interstellar space is the subject of a separate report by C. S. Beals,* we need not enter fully into it here. One can not, however, write on galactic structure, without touching upon absorption problems. We shall, therefore, consider briefly in this section what methods for deriving the absorption characteristics of a given field are now available to the galactic investigator.

*Popular Astronomy, **52**, 209, May, 1944.

A cursory inspection of Milky Way photographs suffices to show that the obscuring clouds have a very irregular distribution over the sky. The southern Coalsack and the Great Rift in the Milky Way from Cygnus to Sagittarius illustrate the irregular distribution of the absorbing material. For the study of galactic structure, the use of an average coefficient of absorption has only very limited use. Dependable as seem to be the averages derived by Joy from Cepheids (1 mag/kpc) and by Trumpler from galactic clusters (0.7 mag/kpc), they tell us very little about the absorption characteristics for any given region of the sky.

There are two ways in which, for regions directly along the Milky Way, we may obtain information about the amounts of absorption at various distances. We can proceed first by star counts, which make it possible to delineate the more conspicuous individual dark nebulae. From a combined analysis of star counts and data on the distribution of stars of various spectral types, one may deduce reliable values for the total absorption and distance of each particular isolated dark nebula. The regions in between the conspicuous dark nebulae are, however, generally not free from interstellar absorption. The only known way to deduce the amount of absorption in these "open" regions is from an analysis of the observed color indices of stars of known spectral type.

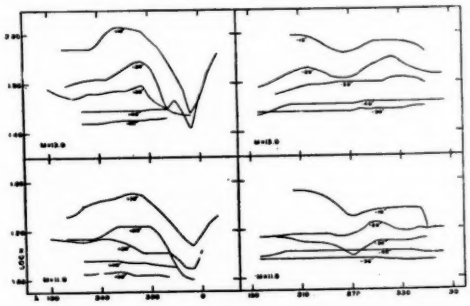

FIGURE 7

THE INFLUENCE OF THE DARK NEBULA IN OPHIUCHUS

The curves on the left show the variations in the logarithms of the counted numbers per square degree of stars brighter than the 11th and 13th magnitude at galactic latitudes +10°, +20°, +30°, +40°, +50°. Deficiencies in counted numbers are present at galactic longitude 330°, latitude +10° to +30°. No such deficiencies are indicated at southern galactic latitudes. Counts of galaxies confirm the hypothesis that these deficiencies are caused by an extended dark nebula.

Local Obscuration. The description and study of the isolated dark nebulae has progressed very satisfactorily during the past fifteen years.

Important contributions have been made by Wolf and others in Germany. Pannekoek in Holland, Schalén, and others, in Sweden and by many astronomers in the United States. It would seem that all of the more important single dark nebulae, or groups of connected nebulae, have been investigated and that their distances and absorptions are tolerably well known. The only regions that are still in need of extensive further investigation are in the quadrant within forty-five degrees on either side of the galactic center.

Among the largest and most conspicuous of these nebulae we list the nearby Taurus and Ophiuchus nebulae and the southern Coalsack, all within 500 light years of the sun, the Orion nebula and the Cepheus flare at 1000 light years or more from the sun, and the remote nebulae associated with the Rift in Cygnus at a distance of about 2500 light years. Because of the presence of numerous foreground stars, and because of the small angular sizes of the more distant nebulae, it becomes difficult to detect and analyze the nebulae farther than 4000 light years from the sun. Individual nebulae at distances beyond 6000 light years are out of reach of present-day methods of detection and analysis.

The study of individual dark nebulae serves a double purpose. First, the results represent information of intrinsic value for the study of the structure of our galactic system. Second, with the regions of excessive local obscuration marked, we can proceed to pay special attention to the relatively clear regions. Studies of colors for stars of known spectral class can then be used to help estimate the residual absorption overlying these relatively unobscured regions.

Colors of B and A stars. The most significant material on colors of distant stars has been collected by Stebbins, Huffer, and Whitford. They have succeeded in deriving extremely accurate photoelectric color indices for B stars within reach from the latitude of Mount Wilson Observatory; their catalogue in *Mount Wilson Contributions,* No. 621 contains the colors for 1332 stars.

The normal colors and mean absolute magnitudes for the various sub-classes of the B stars are fairly well known and, by subtracting the normal color indices from the observed values, a color excess is obtained for each star. There is still considerable uncertainty about the factor by which to multiply the derived excess to obtain the total photographic absorption. In a recent summary by Stebbins (*Astronomical News Letter* No. 16), he suggests that to pass from a color excess in the international scale (ptg. minus pv.) to a fair estimate of the total absorption in photographic light, the observed excess should be multiplied by a factor 4.1. The range of uncertainty is, however, such that the factor may in the end prove to be anywhere between 3.0 and 5.0.

Stebbins' B stars are sufficiently numerous to provide, for any section of the Milky Way north of declination —40°, a fair estimate of the average total absorption for distances to at least 6000 light years from

the sun. There are, however, not enough stars to provide the very detailed information on space reddening required for the analysis of the fine structure of each section of the Milky Way. In some sections the absorbing material appears to have so highly irregular a distribution that the colors of the few B stars can give only a very approximate picture of the amount of reddening at various distances.

To obtain the desired detailed information we need clearly a class of stars of very high luminosity, but much more abundant than the B stars. Unfortunately there is no class that satisfies this requirement. If we place the emphasis on large numbers, the A stars are our best choice. Their absolute magnitudes are three or four magnitudes fainter than those of the B stars and we cannot hope to penetrate to 5000 light years without including 13th or 14th magnitude A's in our color surveys.

Extensive studies of color excesses for stars of spectral classes B5 and later have been undertaken at the Upsala, Stockholm, Lick, Mount Wilson, and Harvard Observatories. The data on space reddening thus obtained help to round out the information on interstellar absorption derived from the colors of the B stars. At present only one-quarter of the Milky Way has been studied with anywhere nearly the required thoroughness, but the results already obtained indicate that the analysis for the detailed distribution of absorbing material to a distance of 8000 light years is possible with present-day equipment and techniques. All that is required to complete the task are spectral types and color indices to the 13th magnitude for all B and A stars within ten degrees of the galactic circle.

As the study of space reddening progresses, we add steadily to the list of regions for which the absorption characteristics are tolerably well known. Because of the uncertainties in the mean absolute magnitudes and in the conversion factor to pass from an observed color excess to an estimated total absorption, we can as yet be none too sure about the absorption characteristics of the heavily obscured fields. If, however, it can be demonstrated that, for a certain region, the reddening is slight, then we have not only the possibility to penetrate to great distances, but there will be the further advantage that the remaining uncertainty in the total photographic absorptions will be of little consequence in the analysis for space densities.

Some Transparent Regions. For the next few years it is recommended that investigators pay special attention to the known relatively transparent regions of the Milky Way. The program of isolating the heavily-obscured regions has been completed. It does not seem profitable to continue their study until we shall have learned as much as possible about the stellar distribution and absorption characteristics in the relatively unobscured fields that must serve for comparison purposes.

In the present state of our knowledge it would be difficult to attempt

a listing of all relatively unobscured regions of the Milky Way. On the basis of available color data, it is however possible to prepare a list of some centers that are especally in need of further study. We nominate the following:

1. The region of the great star cloud in Cygnus, galactic longitude, $l = 30°$ to $45°$, galactic latitude, $b = +1°$ to $+3°$, has an average total photographic absorption amounting probably to less than 2 magnitudes at 6000 light years from the sun. Colors of faint Cepheid variables for a region at slightly higher galactic latitudes suggest extreme transparency (total absorption 1.5 magnitude only) to a distance of 30,000 light years (Oort, Oosterhoff).

The dark nebulae in Cygnus are very pronounced. It is here that we see the beginning of the Great Rift, stretching southward to the region of the galactic center. The Rift is a complex phenomenon. In Cygnus the dark clouds, which produce the effect, are mostly at 2000 light years from the sun. In the more southern portions of the Rift, dense dark nebulae are already found at one-quarter or one-fifth of this distance.

2. A region in Cepheus at $l = 70°$ to $75°$, $b = +0°$ to $-3°$ shows an average total photographic absorption of only 0.6 to 0.8 magnitude at a distance of 6000 light years. This region is bordered on the north by a heavy screen of obscuring material, covering most of Cepheus and even the region of the north celestial pole. In these longitudes the absorption to the south of the galactic circle is apparently quite light.

3. A region in Auriga near $l = 135°$, $b = +2°$ is a transparent one, in the general direction of the anti-center of our galactic system. Various color surveys are available and it seems almost certain that the total absorption amounts to less than 1 magnitude at 6000 light years. North of the galactic circle, the entire section of the Milky Way from Auriga to Orion and Monoceros seems (with the exception of a few clearly marked dark nebulae) to be free from large general obscuration; south of the galactic circle we find the large Taurus and Orion dark nebulae.

4. In Monoceros there is a large uniform section of the Milky Way, $l = 180°$ to $187°$, $b = 0°$ to $+4°$, for which the photographic absorption is probably no more than 1 magnitude at 5000 light years from the sun. At present data are lacking for most of the smooth section of the Milky Way from Monoceros through Puppis and Vela to Carina. The limited available information suggests, however, that for all regions, unobscured by local dark clouds, the average photographic absorption is probably no more than for the Monoceros region.

5. The Carina region of the southern Milky Way contains many relatively unobscured fields, between $l = 240°$ to $270°$, $b = -3°$ to $+3°$. From the data at hand it seems that, for the center not obviously affected by individual dark nebulae, the average absorption amounts to less than 1 magnitude at 6000 light years.

6. The Sagittarius Clouds, both the large and the small one, are in

urgent need of further investigation. They are in a section of the Milky Way that is not only rich in stars, but also in overlying dark nebulae! Marked obscuration is present from the Southern Coalsack, through Centaurus, Norma, Scorpio, and Sagittarius and then northward past the Scutum Cloud, through Aquila to Cygnus. The Great Rift in the Milky Way and the giant Ophiuchus dark nebula are part of this patchwork of obscuration.

The meager color data that are now available (mostly Stebbins' colors for B stars) for the Sagittarius clouds indicate that for the clearest region the total obscuration amounts to about 2 magnitudes for a distance of 6000 light years. This represents a considerable obscuration but one still sufficiently small to render it possible to penetrate to great distances.

7. The Scutum Cloud near $l = 355°$, $b = -4°$ is probably the least obscured field in the Milky Way for the section between $l = 340°$ and $l = 10°$. A recent investigation by J. A. Russell at Lick Observatory has confirmed earlier estimates of absorption, of not more than 2 magnitudes at a distance of 10,000 light years. Stebbins' colors for B stars indicate a somewhat larger absorption, but it seems almost certain that the veil overlying the Scutum Cloud is somewhat thinner than that overlying the Sagittarius Clouds.

8. As a final center worthy of careful analysis, we list the regions near $l = 15°$, $b = +5°$ and $l = 20°$, $b = -5°$, on both sides of the Great Rift in Aquila. A photographic absorption of at most 2 magnitudes at a distance of 6000 light years seems indicated for these two centers. In the Rift itself the absorption is very large; between galactic longitudes 330° and 20° the dark clouds already begin to affect stellar distribution at 300 to 500 light years from the sun.

Colors of Cepheids and of Stars in Galactic Clusters. The need for extensive color-spectrum surveys for fields at low galactic latitudes is obvious. The finding of all B and A stars to the thirteenth magnitude and the measurement of their color indices rank high on the post-war agenda. It should, however, be realized that even with our modern Schmidt cameras it will be difficult to go beyond 10,000 light years from the sun if we depend wholly on the B and A stars. The distance to the galactic center is of the order of 30,000 light years from the sun. If we are to be successful in a general explanation of the properties of the galaxy to distances beyond 10,000 light years, we need other methods for estimating the absorbing power of the interstellar haze.

In low galactic latitudes the extension of the exploration to distances beyond 10,000 light years will be extremely difficult. It should be possible to obtain some data on space reddening for objects beyond this limit, but we cannot look forward to obtaining very detailed information. To arrive at the space reddening, we shall have to turn to Cepheid variables and galactic clusters.

During the past decade studies of the colors of Cepheid variables have not been pursued with sufficient vigor. We lack at present for the Cepheids a body of data similar to Stebbins' colors for B stars. With the aid of colors of Cepheid variables it should be possible to derive total photographic absorptions to great distances. From the light curve and period of a Cepheid, guided by spectral data for the brighter Cepheids, we can derive an approximate value of its true color index. This can be combined with the observed color index to find the color excess at the distance of the Cepheid variable. Since it is about as simple to discover a 17th magnitude Cepheid as a 12th magnitude B star, we can through the medium of the Cepheids go to tremendous distances. Photographic and photoelectric studies of colors of Cepheids are urgently needed.

Colors of stars in galactic clusters can contribute much important information on space reddening at great distances from the sun. The work of Trumpler and of Cuffey has already provided us with much useful information on reddening of distant clusters. It is to be hoped that this research will be continued and extended. Here is a field especially adapted to large reflectors. With the aid of efficient slitless spectrographs it should be possible to determine the spectral types of cluster members to the 14th or 15th magnitude. The measurement of the color indices of these stars and of fainter cluster members is a relatively simple project. Not only will it be possible thus to find information about space reddening at very great distances, but one will obtain as well important data about the makeup of the individual clusters, their distances, and, finally, about the arrangement of the system of galactic clusters in our galaxy.

Absorption in High and Intermediate Latitudes. Our survey of the absorption problem has thus far been concerned wholly with fields in low galactic latitudes. The problems are relatively simple when one turns to fields at galactic latitudes 10° and higher. For fields at high and intermediate latitudes the total absorption—and the space reddening —are generally less than along the galactic circle. To find the reddening at various distances one may use the methods that have already been described.

For fields in high and intermediate latitudes the counted numbers of faint galaxies are very useful as indicators for the total amounts of photographic absorption in various directions. An average number of faint galaxies, equal to that for a typical field in the galactic polar cap, is an indication of low total photographic absorption. A deficiency in the counted numbers of galaxies is probably indicative of the presence of galactic absorption. The data on the distribution of faint galaxies, gathered at Mount Wilson and Harvard Observatories, make it possible to derive an approximate value for the total absorption in almost any field outside the belt with galactic latitude —10° to +10°. Because

of the inherent irregularities in the distribution of faint galaxies, the estimated total absorptions may be in error by a much as half a magnitude.

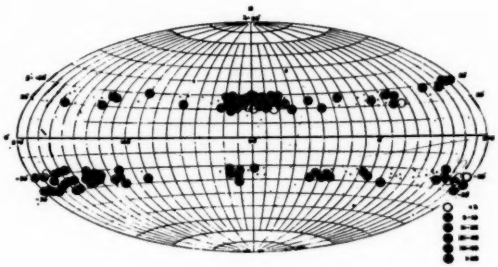

FIGURE 8

NUMBERS OF GALAXIES FOR FIELDS IN INTERMEDIATE LATITUDES

Partial results of a survey for latitudes 20° to 30° of the distribution of faint external galaxies (Shapley).

Counts of galaxies, combined with colors of A stars, give generally a fairly accurate picture of the distribution of absorbing material for any field in intermediate latitudes. Most of the absorbing material is apparently confined to within relatively small distances of the galactic plane. The available evidence for extended dark nebulae at large distances from the galactic plane is not convincing.

V. PROBLEMS OF STELLAR DISTRIBUTION

The Galactic Polar Caps. A knowledge of the stellar distribution for the regions around the north and south galactic poles is basic for galactic research. From the data on the distribution for the polar caps, we may derive information concerning the "thickness" of the galactic system near the sun. A comparative study of the stellar distribution for fields in intermediate latitudes and for the polar caps can give information to show whether the sun is in a region of average, abnormally high, or subnormal star density. Finally, it has been shown by Kapteyn and Oort that, from a comparative study of the stellar distribution and the distribution of velocities in the galactic polar caps, one may derive very useful information about the dynamical properties of the galaxy.

For the north galactic polar cap the data on the stellar and velocity distribution are already becoming quite abundant. We summarize them briefly as follows:

1. Star counts are available to the 18th photographic magnitude. The weak part of the counts is at $m = 12$ to 14, where there is a possibility of a small scale error in the magnitudes. The Warner and Swasey and Harvard Observatories are now engaged on a program to provide ac-

curate counts to m = 18 for an area of 100 square degrees centered on the north galactic pole. The most urgent need is to extend the counts to m = 21 or 22.

2. The classification of stellar spectra in the north galactic polar cap is urgently in need of further attention. The Henry Draper Extension spectra are not of very high quality for this part of the sky. Some preliminary tabulations of the statistics for the spectral distributions have been published by Malmquist, but the complete material has not yet been published. In addition to Malmquist, Morgan at Yerkes, Vyssotsky at McCormick, and Nassau at the Warner and Swasey Observatory, all are working on the problem.

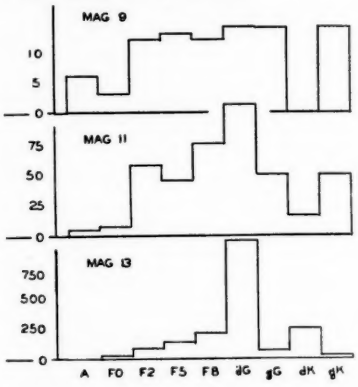

FIGURE 9

THE DISTRIBUTION OF SPECTRAL TYPES IN THE NORTH GALACTIC POLAR CAP

The classification of the spectral types seems well in hand. Within a few years we may expect to have available a considerable number of accurate spectral parallaxes for the brighter stars and regular spectral types, together with giant-dwarf separation, to the fourteenth magnitude. There are probably very few giants among the fainter stars in the polar caps; valuable data on the relative distribution of the G, K, and M dwarfs can, therefore, probably be obtained from color surveys to the 18th magnitude.

3. Proper motions of stars in the north galactic polar cap are known from a variety of sources. *Boss' General Catalogue* and the *Yale Zone Catalogues* for declination +20° to +30° give all the necessary information for the stars brighter than the tenth magnitude. For the fainter stars the McCormick proper motions and Radcliffe proper motions for the Selected Areas provide especially useful material.

4. Radial velocities are still in need of further attention. It is shown in the theoretical work of Kapteyn and Oort that a knowledge of the

distribution of velocities at right angles to the galactic plane is of great importance for an understanding of the dynamics of our galaxy. At several observatories programs are under way to supplement the available information. A considerable number of the stars on Edmondson's program (carried out in cooperation with the McCormick, McDonald, and Mount Wilson Observatories) is in the polar cap; most of his stars are between magnitudes 10 and 12. A program for faint F and G stars is under way at Lick Observatory (Nagtegaal). Quite recently R. M. Petrie at Victoria has embarked on a radial velocity program for 100 A stars and 150 F stars between 8 and 10.

5. Mean parallaxes are known to m = 15. It is very desirable that they should become available to fainter limits. So many of the stars in the polar caps are dwarfs that the mean parallaxes for the eighteenth magnitude may still be quite appreciable. The predicted value of the mean parallax at m = 18 is 0".0017. For that reason the measurement of proper motions to the 18th magnitude would have great value.

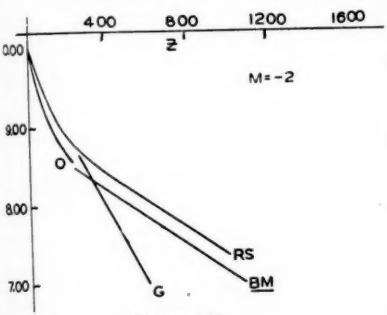

FIGURE 10 *a*

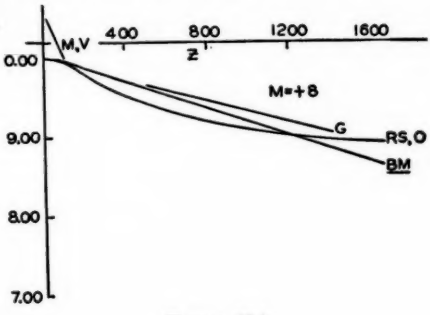

FIGURE 10 *b*

DENSITY DISTRIBUTIONS PERPENDICULAR TO THE GALACTIC PLANE

The curves represent the variations with height above the plane (z, measured in parsecs; 1 parsecs = 3.26 light years) of the star densities in the north galactic polar cap. To show the differences the curves for the giants, with absolute magnitude M = —2, and the dwarfs with M = +8 are printed side by side. M = Malmquist; V = Vyssotsky; R = van Rhijn; S = Schwassmann; G = Greenstein; O = Oort; BM = Bok and MacRae.

6. Density distributions perpendicular to the galactic plane have already been determined separately for each absolute magnitude, between M = —2 to M = +8. The most striking result is that the giants thin out much more rapidly than do the dwarfs. For the giants with M = —2 the star density at 5000 light years above the plane is only one-thousandth part of that near the sun, whereas for the dwarfs with M = +8 the star density at 5000 light years above the plane is still one-twentieth of that near the sun. This variation of relative population of giants and dwarfs has important consequences for the analysis of observed distributions in intermediate latitudes.

7. Cluster-type variables extend apparently to great distances from the galactic plane. Studies at Harvard have revealed variable stars in the galactic polar caps, which are between 30,000 and 50,000 light years from the galactic plane. A knowledge of the distribution of these outlying objects, which help to make up what Shapley has called the "haze" or "corona" of our galaxy, may lead to important information about the dynamics of our galaxy as a whole.

It will be clear from what precedes that our knowledge of the stellar distribution in the north galactic polar cap is in a satisfactory state. Certain added observational data are still needed and there is always a demand for more data and fainter magnitude limits of the various surveys, but there can be no general accusation that the study of stellar distribution in the north galactic polar cap is being neglected. Quite the opposite is true for the south galactic polar cap. Adequate information on star counts, spectral distribution, proper motions, radial velocities, and mean parallaxes is totally lacking. The south galactic polar cap, with its center at declination —28°, is too far south for effective work from most northern observatories. An excellent opportunity for effective research for this part of the sky is given to the observatories in the tropics and in the southern hemisphere. A comparison of comparable statistics in the north and south galactic polar cap is bound to give results of great interest.

Intermediate Galactic Latitudes. In the study of galactic structure, fields in intermediate galactic latitudes play a very special part. For galactic latitudes ±10° to ±25° the absorptions are frequently small and generally determinable. At these latitudes we reach out to a considerable distance from the sun in a direction parallel to the galactic plane, without getting too far away from the central plane itself. With the known stellar distribution for the polar cap as a basis for comparisons, we can for many points in our galaxy compute the number of stars per unit volume (generally called the *star density*) at various heights above or below the plane, expressed in terms of the star density at the same height above our sun. Thus we can see how the star densities at 100-200-300 . . . 1000, etc., . . . light years, directly above or below the sun, compare with the star densities at the corresponding heights for a point at, for example, a distance of 3000 light years for direction of galactic longitude 175°.

The first extensive investigation of stellar distribution in intermediate latitudes was carried out by Oort in 1938. Oort's researches gave the peculiar result that, judging from the distribution at a distance of 500 light years above or below the galactic plane, the sun was in a region of subnormal density. In other words the sun was "in the hole of a doughnut." At greater heights above and below the plane this effect was found to be gradually replaced by a smoothly varying density distribution, with the densities being in excess of those over the sun for the

general direction of the galactic center and below average for the anti-center direction.

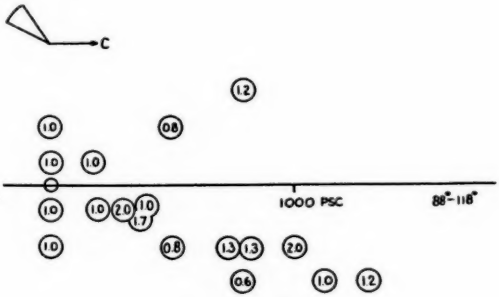

FIGURE 11

STELLAR DISTRIBUTION IN INTERMEDIATE LATITUDES

The diagram shows an example of the distribution at some distance from the galactic plane of stars in galactic longitudes 88° to 118° (Cassiopeia, Perseus). The encircled densities are expressed in terms of the densities at the same height above or below the sun (1 parsec = 3.26 light years).

The run of the star densities at great distances from the galactic plane is in line with what was to be expected from other information about the structure of our galaxy. If the outline is as shown in Figure 1, one would rather expect to find the star densities at the higher levels to increase as one approaches the center of our galaxy. The run of the star densities at the 500 light year level was, however, wholly unexpected. Investigations for fields in low galactic latitudes had generally given the result that the sun was in a region of excessive star density, the so-called "Local Cluster." It would indeed be surprising if the distribution at the 500 light year level would indicate that directly over the sun there is a marked deficiency in stars. It became obviously extremely important to check Oort's results.

In 1941 Bok and MacRae published a paper in which the analysis was carried out by a somewhat more precise method than that used by Oort and with a considerably larger body of data. MacRae has since then investigated three more fields in intermediate latitudes; star counts made by R. H. Baker and Miss Kiefer have also a bearing on the problem.

The new investigations have confirmed Oort's results in part. For the direction of Aquila (at galactic longitude 10° to 20°) the densities for heights of the order of 500 light years above or below the plane are, at distances of 1000 to 2000 light years from the sun, at least 50% larger than the corresponding values directly above or below the sun.

Baker and Kiefer find similar, though on the average slightly smaller, percentage excesses for the range of galactic longitudes 330° to 350° (mostly in Ophiuchus and Sagittarius).

There is apparently no escaping the conclusion that for the general direction of the galactic center the density variations in the galactic plane do not parallel these at some distance above or below the plane. We shall see in the section that follows that for the central sector, at a distance of 1500 light years from the sun, the densities in the plane are below those for the immediate vicinity of the sun. High densities in the plane are in this sector found at distances of 3000 to 5000 light years and more.

The analysis of Bok and MacRae does not, however, confirm the existence of marked excesses for the anti-center half of the Milky Way. At a distance of 500 light years above or below the plane, irregular fluctuations are found, but no systematic trend is observed. At higher levels the decreases, to be expected because of the general galactic density gradient, become quite marked.

The problems of stellar distribution in intermediate latitudes will require much attention in the years following the war. The analysis for stellar distributions will have to be carried out area by area, with each new field requiring a careful survey of colors of stars of known spectral types and of the distribution of galaxies. To supplement the researches of the past few years, which were largely based on general star counts only, we shall require detailed investigations involving the analysis of the observed distributions for narrow intervals of spectral class.

For the immediate future the analysis of distributions for the B8 to A2 stars promises results of the greatest interest. When, later on, we shall know how to separate the giants and dwarfs among the faint G and K stars, it will become possible to obtain results of great value from studies of the distribution of G and K giants.

The lack of agreement in the general character of the derived densities in the galactic plane and for a height of 500 light years above or below the plane gives one the uncomfortable feeling that there is something radically wrong, either with the analysis at low latitudes or with the analysis for intermediate latitudes. Needed above all are careful analyses, at a few critical galactic longitudes (especially for longitudes within 45° of the direction toward the galactic center), for narrow strips at right angles to the Milky Way with latitudes from 0° to 25°. It will be especially advantageous to select at first a few relatively transparent strips, for which the absorption characteristics can be derived with certainty from counts of galaxies and colors of B and A stars. A combined analysis of star counts and spectral distributions in two or three strips should go far toward clearing up the existing difficulties.

Low Galactic Latitudes. The solution of the problems of local structure in our galaxy will, in the end, have to come from analyses of the

stellar distribution for fields in the Milky Way. Studies for intermediate latitudes may yield the broad outlines of the galactic system, but for information about the details of galactic structure within 10,000 light years of the sun we shall have to examine the stellar distribution for fields within ten degrees of the galactic circle.

There are numerous special problems associated with the study of a star field directly in the Milky Way. We have already mentioned the most important obstacle of all, that being lack of definite information on the absorption characteristics of each particular field. If we base our analysis on general star counts, made without reference to spectral class, we encounter as further difficulties, first, troubles with the scale and zero point of photographic magnitudes and, second, lack of sufficient information about the general luminosity function and of the fluctuations in the shape of this function with direction and distance from the sun. To avoid the uncertainties arising from the great spread in the absolute magnitudes for the stars at large, we naturally turn to the separate analysis for each spectral group. The resolving power of the analysis is then improved, but there still remain a number of sources of error. The separation of the giants and dwarfs in the spectral classification of faint stars is, for most surveys, by no means as definite as one would like to see it and the presence of some systematic errors in the classification system seems almost unavoidable. Also, much work remains to be done on the derivation of mean absolute magnitudes and dispersions for various spectral types.

At low galactic latitudes general star counts are mainly of value for the reconnoitering of a section of the Milky Way. They serve, first, to delineate the regions of marked subnormal surface density that are almost certainly affected by localized obscuration. The second function of general star counts is to locate with certainty those areas in the Milky Way for which the stellar distribution to faint limits of apparent magnitude is still reasonably uniform. Uniform areas of high surface density are the ones that hold the greatest promise of definite results from color-spectrum surveys. Thirdly, an analysis of general star counts allows one to derive some very approximate results about the stellar distribution for a given direction.

The available data on stellar distribution for low galactic latitudes do not support the thesis that our sun is located in a region of subnormal star density. For most directions in the galactic plane the star density for the stars at large (the *star density* representing again the numbers of stars per unit volume at various points in our galaxy) seems to drop with increasing distance from the sun. This same phenomenon is present to a greater or lesser degree in the density functions for the separate spectral classes. We find occasionally some indication for the presence of strictly local condensations, but these are of limited size only. The only direction for which average star densities in excess of those near the sun are indicated is toward the galactic center, where, at distances

of 3000 to 5000 light years from the sun, densities greater than for the vicinity of the sun are found.

The general star counts indicate that the star densities decrease with increasing distance from the sun for star fields in the half of the Milky Way from Cepheus (galactic longitude $l = 60°$) through Auriga, to galactic longitude, $l = 240°$, near Carina in the southern hemisphere. In Cepheus, Miss Risley finds an average star density equal to that near the sun for distances to 2000 light years; the density drops beyond this distance. In Cassiopeia, Perseus, and Auriga, the researches of R. H. Baker and his associates show fairly constant star densities up to 1000 light years from the sun, but rapidly decreasing densities beyond this distance. For Taurus, McCuskey's star counts show that the star densities have a negative gradient. In Monoceros the dropping off in the general star density is not very marked. When the maximum permissible value for the photographic absorption is used, fairly constant values of the star density are found to a distance of 5000 light years; there is, however, definitely no increase in the densities at great distances. A preliminary analysis of general star counts for other sample fields in the smooth section of the Milky Way from Monoceros to Carina supports the presence of negative density gradients at distances of 2000 to 4000 light years from the sun.

The rich section of the Milky Way from the η Carinae nebula to the Southern Coalsack seems to be quite transparent. We shall see below that we find here some unusual concentrations of B and A stars, but for the stars at large the densities are either constant or gradually decreasing.

No definite information is as yet available for the arc from the Southern Coalsack to the central regions in Sagittarius. Recently some very interesting results have, however, been published for the section from Sagittarius to Aquila. At Lick Observatory, Weaver has analyzed the stellar distribution for a portion of the Rift in Aquila and J. A. Russell has carried out an investigation of the Scutum region. In agreement with previous results from star count analyses, they find an initial decrease in the star density, with a minimum at 1500 to 2000 light years, followed by marked increases at greater distances. The various analyses seem to indicate that, after traversing some sort of a "gap" in the Milky Way, one approaches the dense central portions of our galaxy.

In Cygnus we find close to the galactic circle, average densities which are constant to approximately 3000 light years from the sun. Beyond that distance the star density seems to drop off, but the computed rate of decrease is quite sensitive to the assumed value of the photographic absorption. There is no indication of a gradual increase in the star densities at great distances.

In the analysis for space densities for *separate spectral classes* one encounters a wide variety of results. Every spectral class appears to have its own peculiar distribution and there is little indication for a relatively

smooth and uniform mixing of the various types.

The densities of the B0 to B5 stars drop sharply with increasing distance from the sun for the half of the Milky Way between galactic longitudes, $l = 60°$ and $l = 250°$ (Cepheus to Carina). The rate of decrease is slow for the Cygnus direction ($l = 40°$). There is no indication of any marked decrease of density with distance for the B stars in Carina ($l = 254°$) and Crux-Centaurus. The B stars in Sagittarius and Scutum show very markedly the sharp initial drop, followed by a subsequent rise in star density.

The distribution of the B8 to A2 stars shows that there exist numerous condensations of these stars within 1500 light years of the sun. The condensations in Cygnus and Carina are the best known ones, but by no means the only ones. Beyond 2000 light years it becomes quite difficult to recognize the local condensations. In the anti-center half of the Milky Way, the A star densities begin to drop off markedly at a distance of about 2000 light years. The rate of decrease is much less for the Cygnus fields and probably absent in Carina. The rise in star density at great distances is marked for the direction of the center.

The densities for the giant G and K stars are inaccurate because of the uncertain contributions from the dwarfs of the same spectral types. The available data indicate that, for distances up to 1200 or 1500 light years, the average densities are quite uniform and approximately equal to those near the sun.

The F stars, which thus far have received very little attention, exhibit some very peculiar characteristics in their distribution. There is little material available as yet but, for the few directions for which sufficient data have been published, there exists evidently a sharp dropping off in the densities for the F stars, with an average density of one-quarter that near the sun at distances of the order of 800 light years. The puzzling behavior of the distribution of the F stars is worthy of much further investigation.

The foregoing summary is in itself a plea for ever more data on spectra, colors, magnitudes, and star counts. The only problems today are, 1, which classes of stars should have preference and, 2, on what centers should we first concentrate our attack. The author's answer to the second part has already been given in the section on absorption problems. With respect to the first part, it would seem that for many reasons the B, A, and F stars should be given preference over the later types. In recent years the early B stars have received much attention, and justly so. For the first years following the end of the war the B8 to A2 stars ought to be made the subject of extensive investigations.

We have alreadys indicated in earlier sections that the recent increases in our information on the proper motions and the radial velocities of the B8 to A2 stars make it profitable to undertake anew the study of the distribution of their absolute magnitudes. The mean absolute mag-

nitudes and dispersions that are in use today are largely based on investigations carried out more than fifteen years ago. These means and dispersions play such a critical rôle in galactic analysis that every effort should be made to derive more nearly accurate values than are available today.

Much work remains to be done on spectrum-color surveys of B8 to A2 stars in low galactic latitudes. A number of these surveys (for perhaps a dozen well-selected fields at first), complete to the faintest apparent magnitude limit within reach of modern telescopes, should contribute greatly to our knowledge of interstellar absorption and of local structure in our galaxy. The inclusion in these surveys of a few strips at right angles to the Milky Way, reaching from latitude 0° to 25°, would finally provide the material needed for unifying the results derived from studies in low and intermediate latitudes.

It would be premature to attempt now the drawing of a sketch to show the present state of our knowledge of local structure in the galactic system. One could only indicate that the sun is probably in a region where the density is slightly higher than average and that regions of really high star density occur in the central portions of our galactic system.

In concluding our survey we should mention, however, that there is already available good indirect evidence to show that our sun, and the entire surrounding region now included in our surveys for local structure, is in a thin part of the galactic system. This evidence is derived by comparing the computed total "surface brightness" for the regions around the sun with the observed surface brightness in various parts of typical spiral nebulae. The computation for the region around the sun can be carried out by putting together the contributions to the computed surface brightness from all stars contained in a cylinder at right angles to the galactic plane.

This comparison has been carried out by several astronomers, first, by Seares at Mount Wilson. A report based on extensive new computations was published by Mowbray in the December, 1940, issue of Popular Astronomy. Mowbray's results confirm those obtained previously; the surface brightness of the region around the sun proves to be so small that, to find a region of comparable surface brightness in the Andromeda nebula, or in the spiral Messier 33, we have to look well outside the limits of the recognized spiral arms.

In our explorations of local galactic structure, we are obviously dealing with the thin outer portions of our galactic system. The increase in star density at 3000 to 5000 light years for the quadrant of the galactic center may be the first indication that we are coming to the dense, main spiral body of our galaxy. The great star cloud in Sagittarius is not necessarily the center itself; it marks probably either an outer edge

of a massive spiral arm, or the outer parts of a large lenticular central body, measuring 20,000 or more light years across.

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Seares-Ross-Joyner: The catalogue of magnitudes and colors north of +80° is published in *Carnegie Inst. Publ.* No. 532. For recent papers by Seares and Joyner see: *Ap. J.*, **98**, 244, 261, 302, 1943, *Mt. W. Cont.*, Nos. 683, 684, 685. Also an article in *M. N.*, **103**, 281, 1943.

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The Planets in September and October, 1944

Note: Greenwich Civil Time is used unless otherwise stated. To obtain Eastern War Time, subtract 4 hours; Central War Time, 5 hours, etc. The information is taken from the *American Ephemeris and Nautical Almanac*.

Sun. During this period the sun will be moving southward at its most rapid rate. Its declination will change from $+8° 25'$ to $-14° 0'$. The sun will cross the equator on September 23, thus marking the autumnal equinox and the beginning of autumn. It will move from Leo through Virgo to the western border of Libra. About the middle of October it will pass very close to the bright star Spica, α Virginis.

Moon. The phases of the moon will occur as follows:

		d	h
Full Moon	September	2	20
Last Quarter		9	12
New Moon		17	13
First Quarter		25	12
Full Moon	October	2	4
Last Quarter		9	1
New Moon		17	6
First Quarter		24	23
Full Moon		31	14

It will be noticed that two full moon phases occur in October. These are the ones for this year which are called the *harvest moon* and the *hunter's moon*, in order. The relation of the moon's orbit to the horizon in the northern hemisphere at the times of these full moons is such as to make the moon especially conspicuous in the early evenings, hence the special names. The moon will be nearest the earth on September 3 and October 1 and 30; farthest from the earth on September 17 and October 14.

Mercury. This planet will vibrate rather rapidly with reference to the sun during these two months. On September 6 it will be at inferior conjunction; on September 22 it will reach a point of greatest elongation west of the sun; on October 20 it will be at superior conjunction. At the time of greatest elongation west it will be well situated for morning observation in the northern hemisphere. It will be about eight degrees north of the sun and will appear on the eastern horizon more than an hour before sunrise.

Venus. Throughout this period Venus will move eastward more rapidly than the sun. It will gain more than an hour on the sun. It will, therefore, become progressively later in setting after the sun. At the end of the period it will be more than nine degreess south of the sun, an unfavorable feature for observers in the northern hemisphere.

Mars. Mars will be becoming more deeply immersed in the glare of the sun, and will be invisible throughout the two months. At the beginning Mars will be more than an hour east of the sun but at the end, only eighteen minutes of time east.

Jupiter. Jupiter, having been in conjunction with the sun on August 31, will gradually fall behind the sun in their motion eastward. As a consequence, Jupiter will become a brilliant morning star toward the end of October. The fact that it will be more than eighteen degrees north of the sun on October 31 will accentuate this feature for northern observers.

Saturn. Saturn will be well situated for morning observation during these two months. On October 3 it will be in quadrature, ninety degrees west of the sun. This means that it will be near the meridian at sunrise on and near this date. It will rise earlier from day to day.

Uranus. Uranus, like Jupiter and Saturn, will be in the morning sky. On September 5 it will be in quadrature west of the sun. After September 19 its motion will be slightly retrograde. On October 1 it will be in Taurus, a short distance northeast of Aldebaran.

Neptune. Neptune will gradually disappear in the evening twilight. On September 27 it will be in conjunction with the sun. During these two months Neptune will be within a degree of the equator. This information is of little value, however, since the planet is too near the sun to be seen.

Occultation Predictions for September and October, 1944

(Taken from the *American Ephemeris*)

Date 1944	Star	Mag.	IMMERSION Greenwich C.T.	IMMERSION *a*	IMMERSION *b*	IMMERSION Angle E from N	EMERSION Greenwich C.T.	EMERSION *a*	EMERSION *b*	EMERSION Angle E from N
			h m	m	m	°	h m	m	m	°
	OCCULTATIONS VISIBLE IN LONGITUDE +72° 30′, LATITUDE +42° 30′									
Sept. 1	30 Capr	5.4	6 1.1	—0.4	+0.7	30	6 52.0	—1.3	—1.9	289
10	χ^1 Orio	4.6	7 19.6	—1.4	+0.1	124	8 6.3	—0.2	+3.3	209
14	12 B.Leon	6.3	8 6.5	0.0	+0.7	113	9 4.4	—0.1	+1.5	262
19	80 Virg	5.8	23 0.7	—0.6	—1.7	109	0 5.7	—0.2	—1.9	294
24	58 Ophi	4.9	23 10.1	—1.9	—0.3	85	0 32.4	—1.7	—1.3	285
26	28 Sgtr	5.8	2 33.8	—0.9	—0.8	73	3 40.5	—0.7	—1.4	273
30	74 Aqar	5.9	7 12.5	—1.0	—2.0	110	7 54.4	+0.1	+1.0	201
Oct. 7	372 B.Taur	6.1	6 20.3	..	..	8	6 49.9	..	..	321
23	222 B.Sgtr	5.6	22 40.8	..	..	24	23 23.9	..	..	323
28	ψ^3 Aqar	5.2	2 40.0	—1.6	0.0	75	3 49.8	—0.9	+0.4	226
28	33 Pisc	4.7	21 9.7	—0.2	—0.1	134	21 33.4	—0.4	+3.4	182
	OCCULTATIONS VISIBLE IN LONGITUDE +91° 0′, LATITUDE +40° 0′									
Sept. 1	30 Capr	5.4	5 52.8	..	..	359	6 18.2	..	..	320
10	χ^1 Orio	4.6	7 3.5	—0.4	+0.9	106	7 56.7	0.0	+2.2	228
12	79 Gemi	6.3	8 40.3	—1.0	—1.1	148	9 11.5	+0.6	+3.9	207
24	58 Ophi	4.9	22 31.6	—2.0	+0.3	98	23 59.2	—2.1	—0.5	283
26	28 Sgtr	5.8	2 12.1	—1.5	0.0	62	3 24.5	—1.6	—1.6	288
30	74 Aqar	5.9	6 53.3	—1.4	—1.0	92	7 50.9	—0.4	+0.6	214
Oct. 6	302 B.Taur	6.1	11 28.3	—1.7	+0.7	58	12 41.1	—1.4	—1.6	280
23	222 B.Sgtr	5.6	21 59.5	..	..	29	22 43.8	..	..	328
28	ψ^3 Aqar	5.2	2 8.1	—1.6	+1.2	55	3 24.6	—1.7	+0.4	247

OCCULTATIONS VISIBLE IN LONGITUDE +120° 0′, LATITUDE +36° 0′

			h	m	m	m	°	h	m	m	m	°
Sept. 7	BD+11°445	5.9	7	49.7	−1.6	0.0	123	8	23.0	+0.4	+3.6	186
26	28 Sgtr	5.8	1	8.8	−2.3	+1.2	68	2	29.4	−2.2	−0.8	298
30	74 Aqar	5.9	6	4.6	−1.7	+1.0	57	7	21.2	−1.7	+0.3	245
Oct. 4	μ Ceti	4.4	6	36.9	−1.4	+1.0	92	7	36.2	−0.7	+2.4	210
6	302 B.Taur	6.1	10	30.6	−1.5	+2.2	49	11	48.7	−2.4	−0.2	273
6	i Taur	5.1	13	37.9	−1.8	−1.2	100	14	52.7	−1.6	+0.2	240
7	BD+20°1105	5.9	13	19.7	−2.2	+0.1	81	14	46.4	−1.9	−0.8	268
28	ψ^3 Aqar	5.2	1	23.4	−1.0	+2.2	38	2	26.2	−1.7	+0.7	276

OCCULTATIONS VISIBLE IN LONGITUDE +98° 0′, LATITUDE +30° 0′*

Sept. 1	30 Capr	5.4	5	22.7	−1.3	+2.2	25	6	21.0	−2.8	−1.4	293
10	χ^1 Orio	4.6	..	..	..	..	..	7	33.6	+0.6	+2.8	207
26	28 Sgtr	5.8	1	58.9	−2.4	−0.1	80	3	24.6	−1.8	−0.8	271
26	30 Sgtr	6.2	4	46.2	−0.6	+0.1	55	5	46.3	−0.8	−1.5	287
26	BD−22°5183	7.2	22	31.5	−1.1	+0.1	115	..	..	..	..	..
28	BD−20°6055	7.2	5	54.1	−2.5	−2.7	124	..	..	..	..	..
28	BD−19°5950	7.1	6	44.8	−0.1	+1.0	32	..	..	..	..	..
30	74 Aqar	5.9	6	53.5	−2.9	−2.3	115	7	34.3	+0.2	−2.8	186
Oct. 6	302 B.Taur	6.1	11	11.9	−2.5	−0.4	91	12	35.3	−1.9	+0.5	243
6	i Taur	5.1	14	19.1	−0.8	−2.0	114	15	17.2	−0.8	+0.2	236
7	372 B.Taur	6.1	5	46.3	+1.3	+4.3	7	6	10.0	−2.0	−1.8	320
25	BD−21°5729	6.8	3	57.5	−3.9	−5.6	142	..	..	..	..	..
25	BD−15°6180	7.1	22	53.6	−1.3	+2.6	32	..	..	..	..	..
28	ψ^3 Aqar	5.2	1	43.4	−1.9	+1.3	67	3	3.4	−1.8	+1.3	234

*Computation by Tecla Combariati and J. Lynn Smith, communicated by Captain J. F. Hellweg, Superintendent U.S. Naval Observatory.

The quantities in the columns *a* and *b* are given for the purpose of making these predictions useful for any place within 200 miles of the point indicated. The procedure is as follows: Subtract the longitude of the point given from the longitude of the place in question; multiply the result in degrees, taking the signs into account, by the quantity under *a* for the star to be observed; similarly, with the latitude, using *b*; apply the sum of the products, with its proper sign, to the Greenwich C.T., and obtain the predicted Greenwich Civil Time for the phenomenon at the place of observation. To obtain Eastern Standard Time it is necessary to subtract five hours; Central Standard Time, six hours, etc.

METEORS AND METEORITES

Meteor Notes from the American Meteor Society

By CHARLES P. OLIVIER, President

A variety of circumstances has prevented the reduction of any observations in my hands in time for these Notes and I do not have any review of published work which can be given at the moment. However, as it appears possible that our members might like to see in tabular form how our Society has progressed since its founding, these Notes are used for a brief résumé.

The A.M.S. was launched in the fall of 1911, but I had begun meteor work as a boy in 1898 and on many occasions thereafter had been aided by young men whom I knew. So it is proper to add the meteors observed in 1898-1910 to our total. The data for the various years are not wholly comparable. This is due to several causes. First, up to 1928 most of the meteors were plotted or at least fully recorded individually. After that date, through the press we sought

the help of the general public, especially in August and November, so the percentage of meteors *counted* versus *plotted* grew immensely. This state of affairs continues to be true. As reported, however, for example, 50 meteors counted (with time intervals, etc., given by the observers) have an equal standing with 50 plotted. As for fireballs, a different system is used. A special table is given in each annual report for them. But each fireball is counted only once, though often from two to fifty—in one case over 400—observations were sent in on the same object. If each observation had been listed separately in our reports, several thousand would be added to the total that will be given below. Until 1926, miscellaneous observations were not usually counted for the particular year, so totals covering several years have to be given. Up to 1928, all publications were issued from the Leander McCormick Observatory, University of Virginia, to the staff of which I was attached most of those years. Since July, 1928, all publications have gone from the Flower Observatory, University of Pennsylvania, our present headquarters. In our publication M4, which covers 1919-1925 inclusive, the yearly totals are not given separately and I have not taken the time to count them up by going over very many pages of tabular matter. These were the years when we were just recovering from World War I, during which our activity almost ceased. However, data for four of these years are given elsewhere, so the other three are simply lumped here. We have also in our files old observations sent us by various persons. I do not know the exact number of meteors represented, but probably there are a thousand or two in all. About 2000 plotted observations by two individuals, which appeared most suspicious and impossible, were rejected at the time and will never be counted. Reports of work which arrive a year or more late, as has sometimes happened, were assigned to the year they arrived. At the moment, it is known that work done by certain persons for as much as three years back is still not in my hands. Of course this cannot be allowed for here in our table. It will be noted that the years 1931-34 are those in which interest was greatest. This was due to the current or expected Leonid showers. While it is true that only in 1931 did a rich display appear, still enough Leonids came in the other years to focus attention upon meteors in general. Also many persons were out of regular employ-

TABLE OF ANNUAL TOTALS

1898-1910	6,200	1928	4,284
1911	476	1929	10,366
1912	854	1930	13,560
1913	1,269	1931	29,013
1914	479	1932	58,328
1915	4,914	1933	61,989
1916	10,532	1934	37,625
1917	3,995	1935	16,494
1918	2,041	1936	21,675
1911-1918 (misc.)	443	1937	22,997
1919, 1920, 1921	309	1938	9,333
1922	2,065	1939	10,742
1923, 1924	3,804	1940	9,447
1925	2,424	1941	6,495
1926	1,483	1942	7,246
1927	3,143	1943	6,594
Totals	44,431		326,188

Total (1898-1943) 370,619.

NOTE: Possibly 30% of the above 370,169 meteors were plotted.

ment and needed amusement or something to take their minds off their personal affairs. Probably these factors helped. At present, too many of our best observers are, to their honor, serving our country for our work to prosper until the war is over, but something continues to be done. With the coming of peace, I hope to see a great revival of interest in the work of the A.M.S. Meteoric astronomy has certainly greatly benefitted up to date by the Society's contributions.

In conclusion, it may be stated that the great collection of data on meteors in our possession, believed to be far the largest in existence, has only been partially reduced. I trust that the future will see many able men come to our headquarters, where every facility would be given them, for more comprehensive studies than have so far been possible with our limited staff, whose time in any case had mostly to be spent upon other types of research connected with our 18-inch refractor.

Flower Observatory of the University of Pennsylvania, Upper Darby, Pennsylvania, 1944 July 20.

Contributions of the Society for Research on Meteorites

Edited by **FREDERICK C. LEONARD**
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The Formation of Meteoritic Iron Oxide

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ABSTRACT

Meteoritic iron oxide occurs in three forms: coarsely lamellar, finely lamellar, and massive. The lamellar forms result from oxidation proceeding parallel to the surface of the metal. The thickness of the lamellae may be proportional to the rate of oxidation. Massive oxide results when electrolysis causes the oxide to invade the metal or when redeposition of dissolved oxide obliterates the original lamellar structure. The action of lawrencite produces a friable, porous type of oxide which is confined largely to specimens in collections. The effect of electrolysis on the differential oxidation of meteoritic minerals is briefly discussed. Three new analyses of meteoritic oxides (by F. G. Hawley) are given (Table 1).

Almost all meteoritic oxide is lamellar, but considerable variations in this characteristic occur, and in some oxides it is not readily discerned. In general, three, or possibly four, types of oxide are met with: coarsely lamellar, finely lamellar, and apparently massive. A possible fourth variety will be mentioned later. Any or all of these kinds may be associated with a single meteorite. The best-known type probably is the coarsely lamellar oxide from the Canyon Diablo, Arizona, Meteorite Crater. The first complete description of this oxide seems to have been Farrington's.[1] He gives an analysis, calls attention to the lamellar structure, and credits Barringer with a hypothesis which explains the origin of the lamellae. It is suggested that the oxidation of a mass of iron might result in the formation of a layer of oxide. Since this would have a greater volume than the original metal, it would break away from the metal. This breaking-away

would provide easy access for moisture, and the process would be repeated indefinitely. Detachment would probably not be complete, and would seldom occur twice in succession at the same place, so that the lamellae would branch and run together at irregular intervals. Another effect of the increasing volume of the youngest layers of oxide would be to cause the formation of cracks in the outer layers. These cracks would ultimately result in the separation of various-sized masses of oxide from the core. This fact would explain the irregular masses of oxide which were once found in considerable abundance around the Canyon Diablo Crater.

Very often, at Canyon Diablo, the rusting masses of iron were buried, so that, even tho cracks were formed, separation did not occur, and the fragments became cemented together with calcium carbonate from the soil and redeposited oxide that had been dissolved in the subsurface moisture. Sometimes this dissolved oxide diffused several inches into the surrounding soil, forming a sort of conglomerate adhering to the outside of the mass of rust. In any case, these rounded masses of oxide, sometimes with cores of residual metal, have come to be known as "shale-balls." The fragments of shale-balls found on or near the surface have been called "iron-shale." This type of oxide is found associated also with the Willamette, Oregon; Odessa, Texas; Henbury, Central Australia; Boxhole, Northern Territory, Australia; and Hoba West, Grootfontein, Southwest Africa, siderites. This list is probably not complete.

Not all Canyon Diablo irons were converted into shale-balls. One reason may be that many lay on the surface, where moisture quickly evaporates. In such cases they would eventually acquire a thin, hard, relatively impervious, and adherent coating of oxide which would tend to protect the metal inside. Microscopic examination of polished cross-sections of this oxide shows that it, too, is minutely lamellar. Another reason for the failure of many specimens to become shale-balls may be that they contained less lawrencite than the shale-ball iron. Merrill and Tassin[2] reported an abundance of this rust-promoting mineral in their description of the shale-ball iron. The residual cores had also a peculiar structure which conceivably had something to do with it. Several shale-balls were recovered from "Crater 13," at Henbury, Central Australia.[3] One had a metallic core which must have been very rich in lawrencite, as it rusted away with extreme rapidity.

There is another form of lamellar oxide which, as far as I can determine, is not found at Canyon Diablo. In this form the lamellae are paper-thin and much more distinctly marked. As a result, this kind lacks the hardness of the coarsely lamellar variety of oxide and is, in fact, easily friable. Dr. Lincoln La Paz informs me that this type of oxide is found buried at Odessa, Texas, near the meteorite crater there, and that it is invariably associated with a metallic core. I know of only one other occurrence of this type of oxide in association with meteorites, altho I have seen it fairly often on artificial iron. It forms a thick coating around and between several large masses of iron from Crater 13 at Henbury. In both of these cases, the coarsely lamellar oxide also was present. Why one mass of iron produces coarse lamellae and another mass of the same kind of iron produces fine lamellae is not altogether clear, but the process may be associated with the rapidity of oxidation. The occurrence of coarsely lamellar oxide close to the surface, the rarity of metallic cores in shale-balls, and the abundance of lawrencite in such cores as have been found, all suggest rapid oxidation. The finely lamellar oxide, as far as known, always has a metallic core, and, in the case of Henbury at least, its thickness is less than the radii of some

coreless shale-balls. In both cases it was excavated, sometimes from a considerable depth, and in neither case was lawrencite mentioned. These facts suggest a slow rate of formation.

In some meteorites, oxidation does not seem to form lamellae parallel to the surface, but tends to invade the metal at the interface between the kamacite and the taenite. In my specimen of Nativitas, Tlaxcala, Mexico, this oxidation has proceeded just far enough to cause easy disintegration of the remaining metal. In Cookeville, Tennessee, most of the kamacite is swathed in oxide and the analyzed sample contained 27.89% oxide.[4] In Salina, Utah,[5] there is still a little unoxidized kamacite, but in the Coldwater, Kansas, oxidized siderite, all of the metal is gone.[6] When complete, this form of oxidation results in a solid mass of oxide, which is relatively free of cracks and which I will call *massive*, altho lamellae paralleling the original kamacite can usually be discerned, if looked for carefully. The most interesting thing about this kind of massive oxide is the

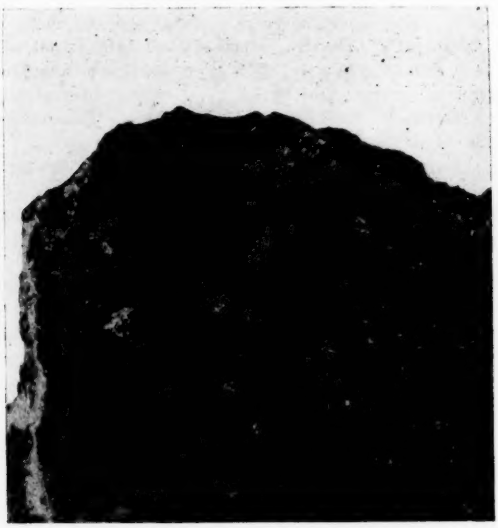

FIG. 1

REMAINS OF THE WIDMANSTÄTTEN FIGURES IN A SPECIMEN OF CANYON DIABLO, ARIZONA, METEORITIC OXIDE
(Photograph by courtesy of L. F. Brady)

occasional preservation in it of traces of the orginal Widmanstätten structure. The crystallization figures are well preserved in Salina, Utah, and Coldwater, Kansas (siderite). Merrill and Tassin allude vaguely to "ghosts" of the Widmanstätten figures in the Canyon Diablo oxide, and L. F. Brady has described a specimen of Canyon Diablo oxide (Fig. 1), in which they are clearly visible.[7] In Coldwater, the original kamacite lamellae can be distinguished in two ways: (*a*) as lighter-colored streaks and (*b*) as rectangular areas of spongy, yellowish oxide. Only the latter type appears in a photograph of Mr. Brady's specimen.

In Salina, the figures are visible because of the lamellation parallel to the original taenite. In the oxidized part of Wood's Mountain, North Carolina, the figures can be distinguished because the taenite has not yet oxidized.[8] These meteorites are all octahedrites, but the structure of ataxites also may be preserved. Near the metal cores of Monahans, Texas, and Nordheim, Texas, the oxide contains a delicate reticulum of residual taenite. At greater distances in Monahans, the taenite has oxidized to a darker oxide, so that the structure is still visible. The oxide of Monahans is not massive, but is basically a shale-ball type.

There are really two kinds of massive oxide. Besides the one previously described, there is another that results from the fact that the oxide is somewhat soluble in ground water, possibly because of dissolved carbon dioxide. Some of the dissolved oxide is carried only a little way and then redeposited in the cracks and between the lamellae of the primary oxide. At first these deposits have a mammillated appearance, but, in time, a solid mass of oxide is formed. This can sometimes be distinguished by its lighter and more variable color, which ranges from sooty-black, thru brown and red, to yellowish shades. The filling of cracks and interlamellar spaces is rarely perfect, so that the presence of cavities lined with mammillated deposits of oxide of various colors also is characteristic. The oxide of the Paulding County, Georgia, iron is of this type.[9] The oxide of Monahans, Texas, is a shale-ball type of oxide, which has begun to be changed into this same type.

Migration of oxide seems to have been especially characteristic of the "meteorodes" found in the crater at Haviland, Kansas.[10] These were originally Brenham pallasites, but, since they occupied the bottom of a pond, they were completely oxidized, and much of the oxide was transported to the outer surfaces, where it formed a solid shell inclosing the fragments of olivine.

The possible fourth type of oxide, previously mentioned, is rarely, if ever, formed in nature, but is all too common in meteorites in collections. I refer to the light, powdery, cellular oxide resulting from the action of lawrencite on the metallic parts of meteorites in a moist atmosphere. The mechanism of this action has been described by Farrington.[11] In the damp air of London, England, the Cranbourne, Victoria, Australia, iron was being converted into this material so rapidly (at the rate of about 10.4 pounds per year) that the British Museum (Natural History) was forced finally to put the meteorite into a nitrogen-filled glass case.[12] An oxide, briefly mentioned as occurring in the vicinity of the Wabar, Arabia, craters may be a natural example of this type of oxide. I have not seen any of it, and it has been too briefly described for me to be certain of its character.

In addition to simple oxidation and the action of lawrencite, there is electrolytic oxidation. Whenever two dissimilar conductors are in contact in an electrolyte, they form a cell and the more anodic of the pair is oxidized. Since iron is 0.19 volt more electropositive than nickel, one would not be surprised if kamacite and taenite were to form such a cell and that the kamacite would be the oxidized member. This reaction is precisely the cause of oxidation between the kamacite lamellae; it is not rare for the kamacite to disappear completely, leaving the taenite more or less intact, as in Wood's Mountain, North Carolina, and Nordheim and Monahans, Texas. Nininger recovered thin taenite lamellae from the rust of the Nativitas, Mexico, iron,[13] and Flight obtained his "edmondsonite" (= taenite) from the rust of the Cranbourne, Australia, iron. Analyses show that the residual metal sometimes found in oxides is often richer in nickel than is the

original meteorite. Schreibersite and kamacite form another such couple, and again it is the kamacite that suffers. In some irons, such as Salina, Utah, and Mount Joy, Pennsylvania, the rhabdites are sometimes found unaltered but surrounded by irregular oxidized areas. Unaltered schreibersite has been observed repeatedly in meteoritic rusts; Merrill and Tassin went so far as to ascribe even the magnetism of the rust to it! This conclusion is almost certainly in error.

Tamman and Ewig[14] found that, in artificial iron, the cementite is 0.032 volt more anodic than ferrite, and should therefore be oxidized first. Perhaps this fact explains the oxide-pearlite found in the native iron of Ovifak, Greenland, and in certain iron meteorites. Since the cores of the Canyon Diablo shale-balls were rich in schreibersite (which would tend to oxidize the metal) and cohenite (which would be oxidized by the metal), it may be that the presence of these accessory minerals had something to do with the formation of shale-balls.

Nothing is known about the electrolytic effects of graphite and troilite nodules. However, the oxidation of the latter would form sulfuric acid, which would hasten the chemical corrosion of the iron.

Electrolytic corrosion explains why oxidation penetrated the Tombigbee River, Alabama, iron along the Neumann lines. Neumann lines are slip-bands in twin relation to the metal around them, and, as such, they are more or less cold-worked. Cold-worked metal has a higher energy content than unworked metal and is therefore less stable, or, in other words, it is anodic to the unworked metal. Here again a couple is formed, and the material in the Neumann lines is converted into oxide. This phenomenon has been observed in other hexahedrites also.

The foregoing discussion does not exhaust the possibilities of electrolytic corrosion, as there are other factors of unknown importance, such as concentration cells and the possibility that the metal is anodic to the oxide itself or to some component of it.

I have here to report (Table 1) three new analyses of meteoritic oxides. The first is of the finely lamellar oxide that covered the irons in the bottom of Crater 13 at Henbury, Australia. The second is of a mixture of old oxide, with a considerable portion of newly formed oxide, from the Sardis, Georgia, iron and the last is a previously unpublished analysis of Canyon Diablo, Arizona, rust. All three analyses were made by Mr. F. G. Hawley, who kindly donated the analysis of Canyon Diablo oxide, which he made several years ago.

TABLE 1. ANALYSES OF THREE METEORITIC OXIDES
(BY F. G. HAWLEY)

	Henbury, Australia	Sardis, Georgia	Canyon Diablo, Arizona
FeO	6.68%	16.75%	7.58%
Fe_2O_3	73.86	58.67	77.55
NiO	5.51	4.63	5.83
CoO	0.49	0.70	0.37
H_2O-	1.92	2.86	6.15
H_2O+	10.25	7.96	
CaO	0.30	0.30	...
Cr_2O_3	...	0.02	...
P_2O_5	0.25	1.28	0.43
SO_3	0.42	0.89	0.20
Insol.	0.20	4.68	0.90
	99.88%	98.74%	99.01%
Pt metals	0.28 oz./ton	0.30 oz./ton	0.25, 0.07, 0.73 oz./ton

The Sardis oxide contained also some chlorine, and the determination of

platinum metals in it was made on a sample containing a considerable proportion of metal. It should be noted that, since the Sardis oxide was formed largely since its excavation, it is very rich in FeO as compared with the other two oxides. I shall have more to say about the composition of meteoritic oxides in another paper.

My thanks are due to Mr. F. G. Hawley for the donation of certain analytical results, to Mr. Stuart H. Perry for some excellent photographs, which were of great value in the preparation of this paper, and to Mr. L. F. Brady for the photograph which is reproduced as Fig. 1.

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ADDENDUM

Since writing the preceding paper, I have measured the thickness of the lamellae in one specimen of Canyon Diablo meteoritic oxide. The average thickness of individual lamellae is 0.175 ± 0.033 mm., but every third or fourth lamella is especially well defined at one edge, thus giving the appearance of wider lamellae. The average width of these wider lamellae is 0.572 ± 0.077 mm.

Illustrations of several kinds of meteoritic oxide are to be found in S. H. Perry's "The Metallography of Meteoric Iron," *Bull. 184, Smithsonian Instn., U. S. Natl. Mus.*, Pls. 60, 67, 68, and 69, 1944. See also refs. ([5]) and ([8]), *ante*, of the present paper.

On the Place of Meteorites in the Cosmos

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ABSTRACT

The place of meteorites in the cosmos is exhibited by means of what is called the Inventory of the Universe (Table 1). A Classification of Fallen Meteorites (Mi) (Table 2) is included in the article for convenience of reference. Several fundamental terms are defined and the subject of the paper is commented on briefly.

A *meteorite* has been defined as a *mass of solid matter*, smaller than a minor planet, either traveling thru space as an unattached unit or still retaining its identity on the Earth or on some other astronomical body onto which it has fallen.[1] In accordance with their definition, meteorites—which have sometimes been disparagingly referred to as "the vermin of the universe"[2]—may be of any magnitude whatever, from the size of the tiniest solid particle to that of a mass

of planetary dimensions; they are, in fact, the smallest discrete astronomical bodies. The literal meaning of the word *meteorite* is a stone or rock from high in the air;[3] in view of the cosmic origin of meteorites, it is perhaps unfortunate that they were not termed *cosmolites;* but it is too late now to hope that this word will ever be adopted for them.

The place of meteorites in the cosmos is well exhibited by means of the device constituting Table 1, which, for want of a better expression, is called the

TABLE 1. THE INVENTORY OF THE UNIVERSE

1. THE SOLAR SYSTEM

THE SUN (a star)

PLANETS

MAJOR PLANETS*

TERRESTRIAL PLANETS: *Mercury* (0), *Venus* (0), *Earth* (1†), *Mars* (2)
JOVIAN PLANETS: *Jupiter* (11), *Saturn* (9), *Uranus* (4), *Neptune* (1)
ULTRA-NEPTUNIAN PLANET: *Pluto* (0)

MINOR PLANETS (called also *planetoids* and *asteroids*): about 1500 known ones, revolving around *the Sun* mostly in the zone between the orbits of *Mars* and *Jupiter*

SATELLITES*: known to all the major planets except *Mercury, Venus,* and *Pluto*

COMETS

METEORITES

THE RINGS OF SATURN
THE ZODIACAL LIGHT AND THE COUNTERGLOW (called also *the gegenschein*) } *Aggregations* of meteorites

METEORITES IN INTERPLANETARY SPACE, revolving around *the Sun* either singly or in swarms

INCANDESCENT METEORITES IN FLIGHT IN THE EARTH'S ATMOSPHERE, producing the luminous phenomena called *meteors*

FALLEN METEORITES, OR METEORITES ON EARTH, OR EARTHLY METEORITES
AEROLITES (stone meteorites)
SIDEROLITES (iron-stone and stone-iron meteorites)
SIDERITES (iron meteorites)
TEKTITES (glass meteorites [?])‡

2. THE STELLAR SYSTEM

STARS (suns), both bright and dark

NEBULAE, both bright and dark, *directly* observable, both visually and photographically§

INTERSTELLAR GASES, *indirectly* detectable from the so-called "stationary" absorption lines to which these gases give rise in certain stellar spectra and from the emission lines observed in the spectra of certain regions of the sky that are devoid of visible nebulosity

COMETS, *inferred* to exist from the apparently hyperbolic heliocentric orbits of some comets

METEORITES

INTERSTELLAR SOLID MATTER, *aggregations* of meteorites causing obscuration and absorption effects observed in connection with certain objects‖ in the galactic system¶ and in connection with certain extragalactic objects**

METEORITES IN INTERSTELLAR SPACE, present either singly or in swarms, *inferred* to exist from the apparently hyperbolic heliocentric orbits of some meteorites that enter the Earth's atmosphere

TABLE 1. THE INVENTORY OF THE UNIVERSE (CONT.)

NOTES TO THE INVENTORY

*The number in parentheses, following the name of each major planet, is the number of its known satellites.

†*The Moon.*

‡A *tektite* may be defined as a piece of natural glass, considered by some authorities to be cosmic in origin; *i.e.,* a possible all-glass meteorite. Since the meteoritic nature of the tektites has never been conclusively demonstrated, they are included in this inventory merely for the sake of completeness—and with a question mark.

§By a *nebula* is meant a cloudy-looking, essentially irresolvable object in interstellar space. *Cf.* this definition with that given in *Webster's Collegiate Dictionary,* 5th Ed., 664, 1939: "*Astron.* One of a large class of celestial structures, of great extension and extreme tenuity, composed of matter in a gaseous or finely divided state." See the writer, *loc. cit.,* n. (2), under Notes and References, *post.*

‖Stars, star clusters, and nebulae.

¶By the *galactic system* is meant the galaxy (*i.e.,* the congeries of stars *etc.*) of which the Sun is a member.

**By *extragalactic objects* is meant objects of any category (including "island galaxies") outside the galactic system (see n. [¶], *ante*).

Inventory of the Universe.[2] In this inventory, the universe is divided into two parts, namely, (1) the solar system, defined as the Sun and all those bodies that are dynamically subordinate to it, and (2) the stellar system, defined as all the rest of the universe or that part of it exclusive of or exterior to the solar system. A Classification of Fallen Meteorites (Mi), or meteorites on Earth, somewhat more detailed than that contained in Table 1, is here included, for convenience of reference, as Table 2.[4]

TABLE 2. THE CLASSIFICATION OF FALLEN METEORITES (Mi)*

AEROLITES (A) = "Stones"
  ACHONDRITES (Ac)
  CHONDRITES (C)
SIDEROLITES (So) = "Irony Stones" and "Stony Irons"
  SIDERAEROLITES (Sa) = "Irony Stones"

  LITHOSIDERITES (Li) = "Stony Irons"
SIDERITES (Si) = "Irons"†

NICKEL-POOR ATAXITES (D_2) and HEXAHEDRITES (H)	94% of Fe and 6% of Ni
OCTAHEDRITES (O) and INTERMEDIATE ATAXITES (D_3)	94%-85% of Fe and 6%-15% of Ni
NICKEL-RICH ATAXITES (D_1)	85%-70% of Fe and 15%-30% of Ni

NOTES TO THE CLASSIFICATION

*The symbol (*e.g.,* "Mi") for each kind of meteorite follows in parentheses immediately after its name.

If meteorites are classified simply as "stones" and "irons," all those listed *above* the line drawn between the subdivisions *sideraerolites* (Sa) and *lithosiderites* (Li) should be considered as "stones" (aerolites, A), while all those listed *below* the line should be regarded as "irons" (siderites, Si).

†Enumerated, *post,* in the order of decreasing percentages of iron (Fe) and increasing percentages of nickel (Ni).

From the foregoing enumeration (Table 1), it is apparent that, even tho meteorites are the humblest members of the astronomical hierarchy, they figure significantly, not only in the solar system but also in the stellar system; hence their study belongs quite as properly to sidereal astronomy as to the astronomy

of the solar system. Just as meteorites alone compose the solitary ponderable link between the Earth and the remainder of the cosmos, so comets and meteorites together constitute the sole substantial tie between the solar system and the system of the stars; and, as astronomy[5] is one of the few sciences that are not Earth-bound, so meteoritics[6] is the only subject that has any material connection with the universe beyond the Earth.

NOTES AND REFERENCES

[1] A *meteor*, on the other hand, has been defined as the *luminous phenomenon* that results from the plunging of a meteorite from space into the Earth's atmosphere. See H. H. Nininger, *Our Stone-Pelted Planet*, xix, 1933, and the writer, "Further Remarks on Meteoritical Terminology," *C.S.R.M.*, **1**, No. 3, 1-6; *P. A.*, **45**, 45-50, 1937.

[2] The word *universe* is employed thruout this paper in its only legitimate scientific sense, *to wit: "Astron.* Properly, the entire celestial cosmos; the totality of the observed or postulated physical whole": *Webster's Collegiate Dictionary*, 5th Ed., 1094, 1939. See also the writer, "Some Astronomical Terms," *Publ. Astron. Soc. Pacific*, **51**, 210-12, 1939.

[3] *Cf.* the [bracketed] discussion on the etymology of the word *meteor* in *Webster, op. cit.*, n. (2), *ante*, 629.

[4] See also the writer, "On the Classification of Meteorites," *C.S.R.M.*, *P. A.*, **52**, 148-51, 1944.

[5] Defined as the science of the universe or cosmos; see the writer, *loc. cit.*, n. (2), *ante*.

[6] Defined as the science of meteorites and meteors; see the sources referred to in n. (1), *ante*.

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Comet Notes

By G. VAN BIESBROECK

COMET VAN GENT. A faint new comet was discovered May 23 at the Union Observatory, Johannesburg, South Africa, by the active observer H. van Gent who as recently as last November was the discoverer of a brighter, though short-lived, comet.

The first information about the new object came through with considerable delay:

1944 May 23.7651 Universal time
Right ascension $9^h 24^m 8$ Declination —49° 20′
Daily motion $2^m 36^s$ east, 42′ north
Magnitude 12 Object diffuse

This indicated that visibility was limited to the southern hemisphere but there was some prospect of later visibility for northern observers. Evidently the comet has been well followed in the south for after a couple of weeks the following orbit was announced, computed by J. Jackson, Director of the Cape Town Observatory:

Time of perihelion	1944 July 18.697	
Longitude of node	202°47′	1944
Node to perihelion	337 22	
Inclination	94 54	
Perihelion distance	2.2257	A.U.

While coming northward, the comet at the same time moves in toward the sun

so that it will remain unfavorably situated until the end of the year. By that time it will be a morning object but so long after perihelion it will have become quite faint.

PERIODIC COMET COMAS SOLÁ was last recorded here June 14-15 at low altitude in the evening sky. It appeared as a very diffuse coma not brighter than a star of magnitude 14. This terminates an unusually long period of visibility of nearly nine months.

Of the comets mentioned earlier only one remains in reach of northern observers. It is the very faint periodic COMET OTERMA (1943 *a*) which in eight years describes an orbit of small eccentricity inside Jupiter's orbit. From the evidence at hand so far it shows no appreciable fluctuations in brightness which contrasts strikingly with the behavior of periodic COMET SCHWASSMANN-WACHMANN 1925 II, also moving in a nearly circular orbit. The latter exhibits rapid and violent fluctuations in magnitude and shape which are hard to account for in an object situated all the time beyond Jupiter.

Since last month an improved orbit for COMET DU TOIT, discovered last May, was computed by F. J. Bobone at Cordoba (Argentina). The new elements are:

Time of perihelion	1944 June 17.520	
Longitude of node	22°17′ }	
Node to perihelion	257 4 }	1944
Inclination	18 39 }	
Eccentricity	0.78079	
Mean daily motion	253″.0	

It thus appears that in about fourteen years the comet describes an elliptic orbit extending a little beyond Saturn. Not until next September will it come within reach of northern observers.

Early this month I scanned the morning sky in the hope of catching an early glimpse of PERIODIC COMET ENCKE which comes to perihelion on August 7, but I failed to see it. It was evidently not bright enough to show over the low horizon illuminated by the dawn. If it is seen at all during this most unfavorable return it will not be until the end of the year.

Williams Bay, Wisconsin, July 13, 1944.

Communications and Comments

Under this heading we shall publish from time to time such material as does not properly fall under any of the established headings of this journal. Here, too, may be found, when occasion arises, articles which the editor may not be willing to give sanction to but which, nevertheless, may be provocative of thought along new lines.

Observed Sunspot Patterns*

Sunspots, like prominences, only give up their patterns of development when they are examined in series like a motion picture. Some interesting patterns both classical and new, correlated in this way from a series of drawn observations made with a small telescope during this last cycle, are presented here.

*Continuation of an article in POPULAR ASTRONOMY, August, 1942, p. 398.

In regard to bridges crossing spots, it seems that in most cases they form over them during their decline, but in one noticeable case the opposite was true. On November 11-13, 1938, a bright bridge dissolved first over a large double spot leaving it single. While bridges are a feature in the dissolution of a spot, this indicates that in rarer cases they may form and disappear again from reunified spots. Round spots are usually bridged symmetrically in half through their centers. Between July 14-15, 1940, one member of a double umbra split again indicating the possibility that members of bridged spots may in turn become bridged. Some umbrae are rounded off by segmentation of their extremities.

The main types of sunspot groups might be classified as follows:

I. Regular pair-group with dominating leader and trailer spots and small central stream.
   (a) Larger leader with vestigial trailing stream.
II. Filled in cluster-group with its spots sometimes linked together as a penumbral network.
III. Isolated round spot.
   (a) Composite single spot (many umbrae) with irregular complexity of nuclear details, within single penumbra sometimes of great size.
   (b) Double or bridged spot within same penumbra.
IV. Completely fragmentary and irregular collections (usually group remnants composed of smaller umbrae).

The most common type of sunspot group is the regular pair-group of which all the other types are variations. Types sometimes verge on each other. The main difference between the pair and cluster types is that in the cluster the central stream fills out to dominate the whole group (example of cluster on October 4, 1937). The clusters often become very complex. The single spot is often the leader-remnant of a group and the spectroheliograph in connection with this sometimes reveals flocculi radiating from an invisible pair-component near it. In relation to magnetism and flocculi, the single spots have unipolar fields, the pair groups have bipolar fields, and the clusters have multipolar fields. Umbral groups have much more permanence than predominantly penumbral structures. The great penumbral group of October 11, 1938, returned as one tiny dot while that of January 5, 1940, (same pair-type) with two big umbrae returned generally intact. Returning groups are usually devoid of most of their penumbra.

In general it seems that regular pair-type groups (especially large ones mostly umbra) are the longest lived and the most stable in shape. Two of the longest-lived groups of this cycle were of almost perfect pair structure. That of March 26, 1938, returned on April 21 and again on May 18. That of January 5, 1940, made reappearances on February 1 and February 27. The pair spreads farther apart with each return. In its last stages, only the isolated leader spot remains. This is shown in the third return of the January 5, 1940, group. Needless to say, big groups last longer than small ones. Other types, particularly the complex clusters, even when of great size, are much shorter lived and more variable in their details. They do not have the stability of the simple pair. The cluster of July 8, 1939, returned without observable trace and that of October 4, 1937, returned as a tiny remnant. In returning groups only the simple pair structure remains while irregular details and central stream dwindle away. The cluster of September 16, 1941, is an example of one that returned as a vestigial spread out pair, having lost its whole maze of central details (seen October 10).

Groups of sudden growth are particularly suggestive of formed disturbance—

pockets bursting to the surface under the action of mysterious hidden forces. The group of May 23, 1938, already mentioned, increased in size about 5½ times in exactly one day (210 to 1150 millionths in area). One small group became very prominent just as it was reaching the limb on November 20, 1938, and may have become a fine display on the other side of the sun. Another one of sudden growth was that of November 28, 1938, which in about three days grew from a tiny group to one of 2100 millionths area, with a numerous central stream. It seems that groups of very sudden growth generally tend toward the numerous cluster type and surpass the average in size. The cluster swarms of July 14, 1938, November 28, 1938, and September 16, 1941, were all of rapid growth.

The occurrence of double-decker groups forming trapezoids is a challenge to thought. The existence of groups in the same or in opposite zones with one directly above the other suggests longitudinal as well as latitudinal belts of disturbance. Examples of double group trapezoids in the same zone are not uncommon with the best seen on July 15, 1938, and September 16, 1941. Groups in opposite zones with the same longitude are quite frequent (example on April 26, 1939). I have even seen some trios in the same longitudinal vicinity (July 8, 1939). I have often found that huge groups are accompanied by inversely small ones in the opposite zone (12 cases). These hint at some longitudinal relationship though they may be only coincidences.

A puzzling phenomenon of this cycle was the great sunspot of January 18, 1938, which belatedly caused the aurora of January 24. The delay in the terrestial effect may have been due to a directional deformation of the sunspot-axis along which the electron beam is supposed to flow. The fission of spots takes place along their latitude. Smaller spots are rounder with less penumbra. Composite spots sometimes achieve great size. The composite leader of one group (on October 10, 1938), was 75,000 miles long and 30,000 miles wide. Other composite giants with complex details were seen on March 24, 1940, and August 31, 1939.

The pronounced secondary peak-period of one year, during this cycle, with spots cropping out every summer, deserves some attention in regard to short period rhythms. This is found in other cycles too with similar periods of from 11 to 17 months. Outstanding solar groups often follow closely upon extended periods of scarcity. That of January 5, 1940, was anticipated in this way. Whenever a dearth occurs during the height of a cycle, something unusual is fairly sure to follow. The spots of January 18, 1938, and January 5, 1940, are some of the giants that followed secondary minima. The largest groups do not necessarily occur in the highest cycles. The record group of this cycle appearing on October 4, 1937, with an area of 3100 millionths was fifth in size since measurements were begun in 1872 having been surpassed by others in the much lower cycles of 1905, 1917, and 1928. A spot of January 24, 1926, reached the greatest area of 3716 millionths. While this miscellany is of no great astronomical significance, it should be of interest to the amateur observer.

LESTER SUSSMAN.

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General Notes

Dr. William Hammond Wright, Director Emeritus and Astronomer of the Lick Observatory, was awarded the honorary degree of Doctor of Laws by the University of California at its commencement in Berkeley on June 25, 1944.

Dr. C. G. Abbot, secretary of the Smithsonian Institution since 1928, resigned from that position on July 1, at the age of 72. Dr. Abbot will retain connection with the Institution as research associate. Dr. Alexander Wetmore is serving as acting secretary, pending the appointment of a new secretary by the board of regents.

Dr. Frederick C. Leonard was, on July 1, 1944, promoted from Associate Professor to Professor of Astronomy in the University of California, Los Angeles. Since July, 1943, Dr. Leonard has been engaged in research at the Lick Observatory, where he will continue in residence until September, 1944, when he will return to the Los Angeles Astronomical Department of the University of California.

Dr. Edward W. Condon, associate director of the Research Laboratories for the Westinghouse Electric and Manufacturing Company, has been elected to membership in the National Academy of Sciences, Washington, D. C. The National Academy of Sciences was incorporated by Congress to report to the United States Government on matters in science and art when called upon. Its present membership numbers 352.

Mathematical Association of America

The twenty-seventh summer meeting of the Mathematical Association of America will be held at Wellesley College, Wellesley, Massachusetts, on Saturday, August 12, 1944, in conjunction with the summer meeting and colloquium of the American Mathematical Society and the meeting of the Institute of Mathematical Statistics. Two sessions of the Association will be held on Saturday beginning at 2:30 p.m. and 7:30 p.m.

The sessions of the American Mathematical Society will be held Sunday and Monday. Four colloquium lectures will be given by Professor Einar Hille of Yale University, the subject being "Selected topics in the theory of semigroups." These lectures will be given at 9:00 A.M. and 2:00 P.M. on Sunday and Monday. At 3:15 P.M. on Sunday Professor C. C. MacDuffee of the University of Wisconsin will give an address "On the composition of algebraic forms of higher degree."

Lectures on Astronomy for the Army

Indicative of the variety of ways in which the English people plan for the welfare and entertainment of the British and Allied Forces in London is the fact that during last winter a series of six lectures in astronomy was given for their benefit. These lectures were given in the rooms of the Royal Astronomical Society in Burlington House, by persons known throughout the world for their work in this science. The lecturers and the titles of the lectures were:

Sir James Jeans, Photographic Astronomy.

Prof. W. M. Smart, The Origin of the Earth.
Mr. B. M. Peek, The Planets and Planetary Observations.
Prof. H. Dingle, The Movements of the Stars.
Mr. W. T. Hay, Life on OtherPlanets.
Mr. F. J. Hargreaves, The Determination of Stellar Distances.

The lectures were attended by large and enthusiastic audiences who asked questions and took part in the discussions which followed the lectures.

Pulkovo Observatory to be Rebuilt

By A. Pobedonostev

As a former defender of Pulkovo Heights, I was particularly happy to learn that the Government had recently requested the Academy of Sciences of the USSR to draw up by November 1 of this year a project for the rehabilitation of the Pulkovo State Astronomical Observatory.

The Red Army and the popular volunteer force raised by the people of Leningrad stopped the German offensive on Leningrad at Pulkovo Heights in September, 1941. The Germans then began a methodical daily artillery and mortar shelling of Pulkovo Hill and the Observatory in particular, although they knew our troops were not there, but on the slopes of the hill. The enemy purposely destroyed this world-renowned treasure-house of astronomical science.

The Observatory's most valuable instruments and scientific works were evacuated in good time, but its priceless library still remained in the building, stored in the basement. Situated on the hilltop, the building was an excellent target, and from day to day and week to week the Germans pounded at it from the ground and air. During the first three weeks of fierce fighting near Pulkovo they fired tens of thousands of shells and mortars at the Heights.

The Army Command of the Pulkovo sector decided that the library must be evacuated. The task was difficult, almost impossible, but in the middle of October, 1941, under incessant German artillery fire, trucks pulled up at Pulkovo, and in a short time all remaining books were removed.

Only a mass of ruins now remains of the Observatory which for more than a century beautified Pulkovo Hill. But the Soviet people will raise a new and still more majestic Observatory which will again carry on work for the good of mankind.

(From *Information Bulletin, Embassy of USSR,* June 13, 1944.)

Book Reviews

Meteorology—Theoretical and Applied, by Hewson and Longley. John Wiley and Sons, Inc., New York. 1944. 452 pp. $4.75.

The book approaches its subject from the theoretical as well as the practical side. The first consists of 185 pages covering the derivation of many of the concepts and formulae of meteorology such as the equation of state for dry air, virtual temperature and height, adiabatic relationships, the Carnot cycle, the thermodynamics of moist air, the psychrometer equation, laws of radiation, atmospheric motions under forces, frontal surfaces, kinematics and dynamics of air motions, turbulence, etc.

The second part of the book deals with the standard subdivisions of the

subject and the application of the theories and equations of the first part.

There are nearly 200 illustrations, problems and exercises at the ends of the chapters, a bibliography at the close of each chapter, and a few tables in an appendix.

The book can be recommended to teachers of elementary meteorology and could be used as a text for students who have had some college physics and mathematics through elementary calculus. E.A.F.

Rockets, The Future of Travel beyond the Stratosphere, by Willy Ley. (The Viking Press, New York City. $3.50.)

At the time this review is being written, thinking people the world over are rocket-conscious to a degree never before reached. This consciousness of rockets is induced not by the idea suggested in the sub-title but by the grim fact of wanton destruction being wreaked upon non-military objectives by means of rockets in an apparently futile attempt to stem the mounting tide of certain defeat. We are again witnessing a demonstration of the fact that agencies which have within them the possibility of being used for the advancement and betterment of the race may also be used for its retardation and its injury.

Turning from the temporary unpleasant connotation of the word "rocket" to the more interesting one presented in this volume, we find ourselves figuratively transported to what seems an imaginary world. A rocket to most persons suggests a form of fireworks used chiefly to amuse children or perhaps to give expression to an impulse for celebrating an important event. Few realize that the principle of propulsion of the rocket, small or large, is vastly different from that of a steam engine or of an internal combustion engine. A rocket brings into a prominence the so-called Newton's Third Law of Motion not previously accorded to it. It is the application of this principle which gives meaning to talk of rockets moving in space beyond the limits of the atmosphere, and even, with a leap of imagination, to interplanetary travel.

One cannot, in a short review, touch upon the many unique and interesting ideas presented in the ten chapters of this book. The idea of traveling from the Earth to the Moon is not new. There are frequent references to it in both ancient and modern literature. The earliest references are fanciful and seem playful to us in this age. The author traces this idea, which always has been an intriguing one to some, from its simplest form to the stage it has reached in our day. Along the line the rocket emerges. It is the further development of this which may lead to results which at present seem incapable of accomplishment.

The reader's interest is heightened from the beginning to the end of the volume. The first six chapters are largely historical, recounting what has actually been done. Chapter seven, The Meteorological Rocket, even is not beyond comprehension, for one can readily conceive of rockets rising higher and higher, and of having self-recording instruments drop back to the Earth with new information. Chapter eight, The Rocket into Cosmic Space, makes greater demands upon our credulity, since this implies a definite separation from the influence of terrestrial gravitation. Chapter nine, The Spaceship, goes a step further and suggests not only an inaminate rocket, separated completely from the Earth, but even a ship with a pilot and, perchance, passengers also. The title of Chapter ten, "Terminal in Space," doubtless needs interpretation. It, to all intents and purposes, proposes the creation of an artificial satellite to the Earth. This surely

will seem to most persons to be beyond the realm of possibility. However, it has often been pointed out that the last half-century has made so many dreams realities that one cannot say with certainty what may or may not happen in the next half-century.

In reading this book, one has the satisfaction of knowing that it is more than fiction. The author has a comprehensive knowledge of the scientific principles involved and hence is not given to making statements merely for effect. If the argument seems strange, it is because it is unfamiliar. The reviewer can testify to much pleasure and great stimulus of thought as a result of reading it.

C.H.G.

A Better Sky, by A. P. Herbert. (Methuen & Co. Ltd., 36 Essex St., London.)

This pamphlet of some thirty pages is concerned with the rather far-reaching project of re-naming the constellations and the principal stars. The purpose in doing so, as stated, is to induce and facilitate an acquaintance with the stars. For instance, Ursa Minor becomes Liberty; Ursa Major, Great Britain; Cassiopeia, United States; Leo, Russia; Cygnus, China; Lyra, Europe Regained; Orion and Eridanus, The Sailor; and so on until we come to Draco, transformed into The Tyrants. The individual stars are given names of cities or persons, past or present, mythical or real, whose names are well known. For example, Vega becomes Paris; Canopus, Robin Hood; Sirius, Smuts; Aldebaran, Marco Polo; β Ceti, Helen of Troy.

The attempt to make educated people more familiar with the splendor of the unchanging sky is, indeed, laudable. To proceed by this plan seems to the reviewer to lead to too great a loss for a possible small gain. The proposed scheme is too thoroughly colored by temporary world conditions. A generation or a century is a short period of time as compared with the long-enduring sky. Names now thoroughly despised by all liberty-loving persons should not be preserved among the stars even though it be in the classification of tyrants.

The stateliness and classical tone of the nomenclature associated with the stars lend a dignity and a charm to them. The fact that the names have come down to us from antiquity suggests the quality of permanency represented more clearly in the stars than any where else in nature.

Those who really wish to know the stars will not long be deterred by names which at first may seem unfamiliar. C.H.G.

Basic Marine Navigation, by Bart J. Bok and Frances W. Wright, Harvard University. (Hougton Mifflin Company, Publishers. 422 pp. $4.50.)

In the brief interval since the inauguration of the Navy College Training Program a number of new texts on marine navigation have been published. These texts appear to fall into three catagories. Some of them follow the good Dutton closely in both its more and its less modern aspects. Teachers have managed to make a fair voyage with Dutton by steering around the derelicts. Others of the new texts lean heavily on elementary mathematics and particularly on spherical trigonometry, in compliance with the much-criticized procedure specified for the M8 course of the Training Program. The third group of texts supposes that students in the wartime navigation courses are trying to learn the most approved methods of modern navigation and that many of these students

will presently serve as navigators. The text we are reviewing is an outstanding example of the third group.

The authors of this book have drawn upon their experience in teaching navigation for V-12 and civilian students and also for officers of the Engineer Amphibian Command of the U. S. Army. They have had the benefit of much expert advice, as the Preface shows. A product of the amphibian course is the thorough treatment of coastwise navigation. Another is the unusual and highly important final chapter entitled "Navigation in Emergencies"; it deals with the approximate kind of navigation that can be practiced from a lifeboat or liferaft.

The book is written in clear and interesting style; it is printed on good paper and is an example of fine bookmaking. The many photographs and diagrams are well chosen and clearly reproduced. Extracts from the *American Nautical Almanac*, H. O. 208, H. O. 211, H. O. 214, and other tables facilitate the solutions of the numerous problems that appear throughout the book. A KIT of Practice Materials is published as a companion to the book. It contains blank forms and charts, with a protractor for plotting courses; it also contains a harbor chart, a pilot chart, a buoyage chart, and star charts. The book and KIT together provide a complete outfit for classwork or for a self-taught course in navigation.

"Basic Marine Navigation" can be recommended to the teacher of navigation, to the reader who wishes to study the subject by himself, and to anyone who desires an authoritative and modern reference book on marine navigation.

ROBERT H. BAKER.

Mr. Tompkins Explores the Atom, by G. Gamow. (The Macmillan Company, New York and The University Press, Cambridge, England. $2.00.)

Mr. Tompkins, the principal character in this story, is already well known to many readers through his experiences, related by the same author, in "Mr. Tompkins in Wonderland." Indeed, this book follows the same plan as that of the former one. It consists of three dreams, one by the wife of Mr. Tompkins and two by himself, and four lectures. The dreams precede and are designed to prepare the way for the lectures, although, for the sake of the plot, they are supposed to have been induced by the lectures. The dreams are fantastic and seemingly unreal, as dreams should be. But the unreality of the dreams becomes the reality of the lectures. By this device the reader is introduced to the very modern ideas which the physicists have developed in regard to the constitution of matter. Even so, as the author admits, the thought is involved and somewhat puzzling to the beginner, and he finds it necessary to reread many paragraphs before they give up their meaning to him.

The author, Dr. George Gamow, a native of Russia, was born in Odessa in 1904, and received his higher education at the University of Leningrad, 1922-1927. Sent to continue his studies at the University of Gottingen, he developed the quantum theory of radioactivity (1928), and later did further research with Professor Niels Bohr in Copenhagen and Lord Rutherford in Cambridge, England. In 1935 he was invited to become Professor of Theoretical Physics at the George Washington University in Washington, D. C., which position he still occupies. He was married in Moscow during a visit to Russia in 1931, and has one son born in Washington in 1935.

The reader, therefore, has the assurance that he is in the hands of one

who knows the field in which he is working, and that the slightly humorous approach does not minimize the soundness of the underlying thought.

The lectures are entitled "The Reality of Atoms," "Inside the Atom," "Holes in Nothing," and "The World Inside the Nucleus." A careful study of them will furnish a good comprehension of the physical theories of today. C.H.G.

Publications Received.—The publishers of POPULAR ASTRONOMY hereby acknowledge receipt of the following named publications and express their great appreciation of the courtesy shown on the part of those who have sent them.

Vol. XLV, Art. 1. "The Relation Between Centriole and Centromere in Atypical Spermatogenesis of Viviparid Snails," by Arthur W. Pollister and Priscilla F. Pollister.

Art. 2. "Lycaenidae of the Antilles (Lepidoptera, Rhopalocera)," by William P. Comstock and E. Irving Huntington.

Art. 3. "New Methods in Stellar Dynamics," by S. Chandrasekhar.

Art. 4. "Studies on Fresh-Water Bryozoa. XIV The Occurrence of *Stolella Indica* in North America," by Mary D. Rogick.

Art. 5. "The Social Behavior of the Laughing Gull," by G. K. Noble and M. Wurm.

Contributions from the Mount Wilson Observatory:

No. 678. "Temperature Classification of Gadolinium Lines," by Arthur S. King.

No. 679. "The Properties of Solar Prominences as Related to Type," by Edison Pettit.

No. 680. "Six-Color Photometry of Stars."

1. "The Law of Space Reddening from the Colors of O and B Stars," by Joel Stebbins and A. E. Whitford.

No. 681. "The Stronger Lines of Singly Ionized Dysprosium and Identifications in the Solar Spectrum," by Arthur S. King and Charlotte E. Moore.

No. 682. "Supplement to the Mount Wilson Catalogue and Bibliography of Stars of Classes B and A whose Spectra have Bright Hydrogen Lines," by Paul W. Merrill and Cora G. Burwell.

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